

BAREC SITE STORM DRAIN ANALYSIS

February 2, 2006

HMH Engineers

Storm Drainage analysis for a proposed development of a 16.5-acre site located
at Winchester Boulevard within the City of Santa Clara.

BAREC SITE STORM DRAIN ANALYSIS

EXISTING CONDITIONS

The BAREC property is a 16.5-acre +/- site that has been used as an agricultural research facility. The site is flat with agricultural open space, a paved driveway area and a small building compound. The existing topography splits the site into two drainage areas; the eastern third of the site drains toward Winchester Boulevard and the western two-thirds of the site drains toward Forest Avenue at the northwest corner of the site. Site drainage enters existing City storm drains in two separate systems:

- 1) Winchester Boulevard system, which flows to the north to Pruneridge and west to an outfall into the San Tomas Aquino Creek box culvert.
- 2) Forest Avenue system, which flows to the west to San Tomas Expressway and into the San Tomas Aquino Creek box culvert.

PROPOSED PROJECT

The proposed project consists of a 6 acre senior housing site, 10 acres of single-family detached residential development and a 1 acre park. Drainage from the site will be conveyed into a new on-site storm drain system connecting to the existing City storm drains. Water quality mitigation will be provided through various measures that could include routing of surface flows through landscaped areas.

DRAINAGE ANALYSIS

A site drainage analysis was performed to determine existing and post-development flows from the site and adequate conveyance of site drainage to an appropriate discharge. The City of Santa Clara design criteria was used, incorporating the Rational Method to determine peak flows. A 10-year design storm was used for design of the underground system and flows from the 100-year design storm must be able to release within street areas without impact to private property. Site grading can be designed to convey the majority of runoff from the developed site into the storm drain system within Forest Avenue. A small portion of the senior site (0.8 acres) will drain into the storm drain system in Winchester Boulevard.

BAREC Property runoff rates – Eastern tributary

The City of Santa Clara has indicated that there is no additional capacity in the storm drain system within Winchester Boulevard. Site grading has been designed to limit the area draining toward Winchester Boulevard to approximately

0.8 acres. The site is at the upper end of the watershed tributary to the Winchester system.

Peak Discharge (cubic feet per second)

Concentration Point	Existing 10-Year	Developed 10-Year
Winchester	1.9	1.5

The proposed storm water discharge from the portion of the site draining into Winchester Boulevard will be at or below the existing peak flow discharging from the site; no impacts to the existing storm drain system within Winchester Boulevard is anticipated.

BAREC Property runoff rates – Western tributary

Drainage from the remaining 15.7 acres (14.7 acres residential and 1 acre park) of the site enter into the existing City storm drain system within Forest Avenue. Existing flows are conveyed on the surface and enter the City storm drain system at the intersection of Forest Avenue and Henry. The project will construct a new storm drain within Forest Avenue to connect the site to the existing storm drain main at this intersection. The flow rates represented below are system flow rates incorporating both on-site and off-site tributary areas.

Peak Discharge (cubic feet per second)

Concentration Point	Existing 10-Year	Developed 10-Year
Forest & Henry	12.8	20.7

The existing storm drain system within Forest Avenue consists of a 36" pipe with a short section of 33" pipe connecting to the San Tomas Aquino Creek box culvert. Pre and post project flows were analyzed in the existing Forest Avenue system and it has been determined that the system has sufficient capacity to convey the higher post-project flows.

Conclusion

The project grading design will limit peak flow discharge toward Winchester Boulevard to flow rates that are at or below existing conditions without impact to the existing system. The existing City storm drain system within Forest Avenue has sufficient capacity to accommodate the increase in peak flow from the proposed site without impact to the existing system. During project design, if increased capacity in the Forest Avenue system is deemed necessary,

improvements may include the replacement of, or a parallel line to the existing 33" pipe connecting to the San Tomas Aquino Creek box culvert with a 36" pipe. Other improvements may include upsizing various elements within the Forest Avenue system or over-sizing segments of the on-site storm drain pipes to slow the system flow time and provide storage within the on-site system.

**STORM DRAINAGE REPORT FOR THE
SUMMERHILL HOMES BAREC DEVELOPMENT SITE**

**STORM DRAINAGE REPORT
FOR THE SUMMERHILL HOMES
BAREC DEVELOPMENT SITE**

8-Feb-06



STORM DRAINAGE SYSTEM DESIGN-BAREC SITE DEVELOPMENT

HMH Engineers has evaluated the capacity of the storm system for the Summerhill Homes and Senior Housing Development near the border of the City of San Jose in the City of Santa Clara. The proposed development site is situated on approximately 16.56 acres of mostly undeveloped land. The site is bordered on the north, west, and south by residential development. The site is bordered on the east by Winchester Boulevard.

Background Information:

The proposed project area is a total of 16.56 acres. During undeveloped conditions, runoff from 5.79 acres drains toward Winchester Blvd or is infiltrated on the grounds. The remaining 10.77 acres drain toward the east into an existing trunk line on Forest Avenue. This trunk line is approximately 3,300 linear feet and extends from the project area into a box culvert in San Thomas Freeway. During proposed conditions, approximately 0.82 acres of the proposed site will drain to Winchester Boulevard, with the remaining 15.74 acres draining toward the trunk line in Forest Avenue.

On December 22, 2005, HMH Engineers obtained information from Vincent Stephens of the Santa Clara Valley Water District indicating that the existing Box Culvert contains 3,300 cfs of water during the 10-year storm event. In order to determine a starting hydraulic grade line at the outfall, we assumed that the downstream invert of the last segment of the Forest Avenue trunk line is sloped at 0.005 ft/ft and will connect to the box at the soffit.

Design Assumptions:

Total Proposed Site Area to Drain to Forest Avenue = 15.74 acres.

Total Drainage Area for the Forest Avenue trunk line was obtained from block maps and can be seen in Attached Figure, Sheet 1-Existing/Proposed Drainage Areas

Runoff Coefficients for Existing Residential Developments = 0.4

Pre-Development Runoff Coefficient = 0.15 to Forest Avenue

Post-Development Runoff Coefficient to Forest Avenue = 0.67

Pre-Development Time of Concentration to Forest Avenue= 18.29 minutes

Post-Development Time of Concentration to Forest Avenue = 24.0 minutes

Mean Annual Precipitation for Site = 14.7

K=0.669

N=0.6

Methodology:

Analysis for the existing and proposed drainage areas and the Forest Avenue trunk line was performed in StormCAD version 5.001. Hydraulics for four of the laterals were also computed to demonstrate their capacity to convey the existing inflows. Local design criteria were used to determine the input parameters for the site. This includes the use of Manning's equation for major losses through the system.

Minor losses in the main trunk line were estimated in StormCAD using both the Inlet and Access Hole Losses, Preliminary Estimate Method (7.1.6.6) and the HEC-22 Energy-Loss Method per the guidance of the Federal Highway Administration Urban Drainage Design Manual (pp. 7-14 through 7-19). The two methods were within 0.5 feet on average, with the HEC-22 method providing a more conservative computation of loss. Minor losses in the laterals were computed by hand using the Preliminary Estimate Method.

Analysis:

As shown in Tables 1 and 2, the existing system has the capacity for the 10-year storm while meeting the city's freeboard requirements. The attached Drainage Area Map and Tables 3 and 4 show the drainage boundaries and the storm drain system results for the proposed development. The addition of the proposed system into the Forest Avenue trunk line will generate a condition that will meet all of the city's freeboard criteria in the trunk line. In addition, we have shown that the lateral inlets meet freeboard requirements as well.

Conclusions:

The Forest Avenue storm drainage system has capacity for the additional flow that the Summerhill Homes and Senior Housing Development will produce during a 10-year event.

BAREC Site
Proposed Drainage Areas

INLET	DA	AREA SF	AREA AC
1	1A	683828	15.70
1	1B	721529	16.55
2	2	160013	3.67
3	3	157553	3.62
4	4	243223	5.58
5	5	229466	5.27
6	6	146401	3.36
7	7	153738	3.53
8	8	151076	3.47
9	9	147971	3.40
10	10	140185	3.22
11	11	151974	3.49
12	12	437204	10.04
13	13	169680	3.90
14	14	175619	4.03
15	15	174384	4.00
16	16	179433	4.12
17a	17a	66750	1.53
17b	17b	93538	2.15
18	18	106349	2.44
19	19	23212	0.53
20	20	37781	0.87

Subtotal acreage	104.46
Area to Winchester	0.82
Total Area to Forest Ave Outfall	103.64

BAREC DEVELOPMENT SITE

DRAINAGE AREAS

Part I (Part of Site Draining to Winchester Boulevard)

Existing Conditions

Site Drainage Area Not to Forest Avenue = 5.79 ac

Impervious Area = 1.42

% impervious = $1.42/5.79 = 0.25$

C factor = 0.3

Proposed Conditions

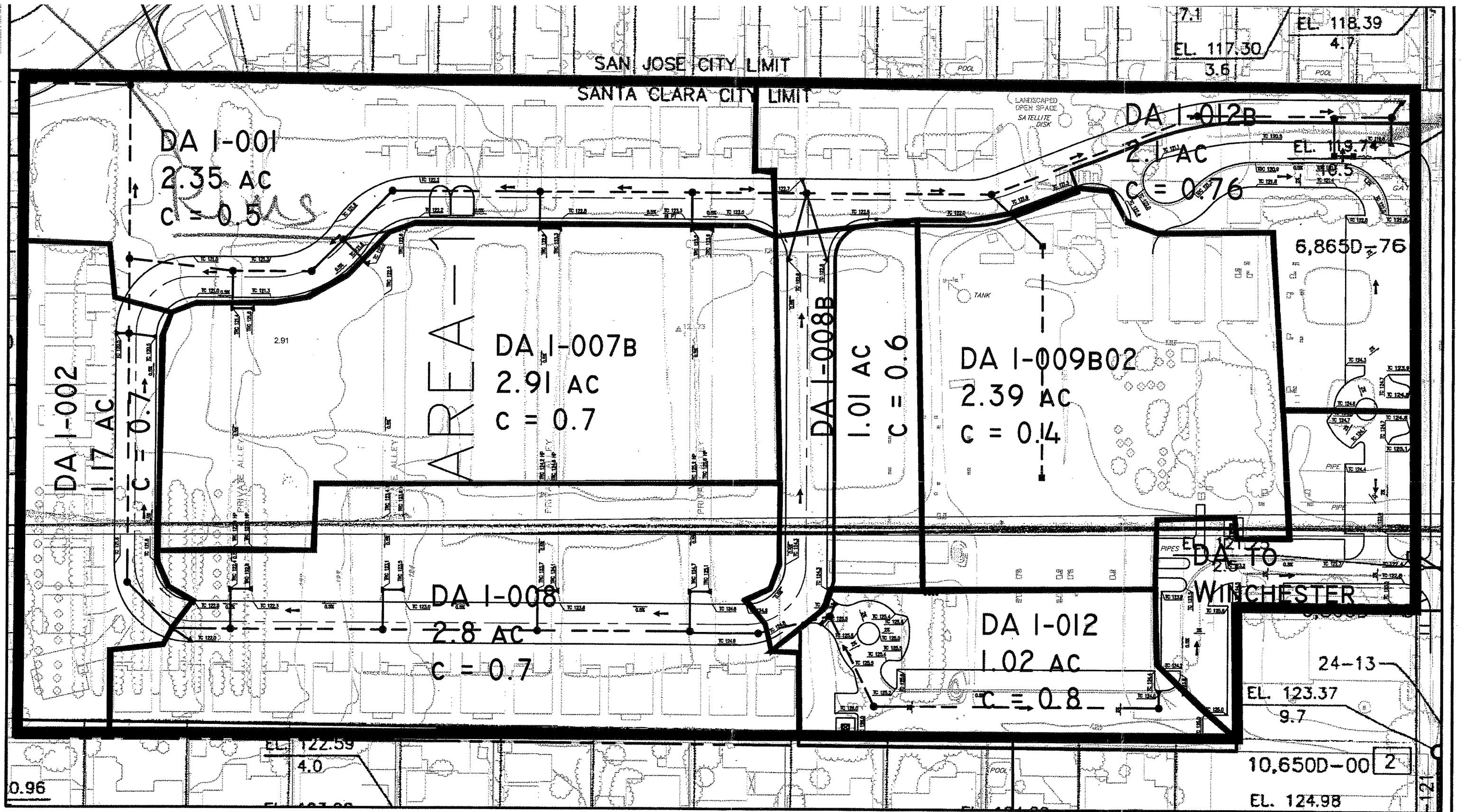
C factor = 0.67

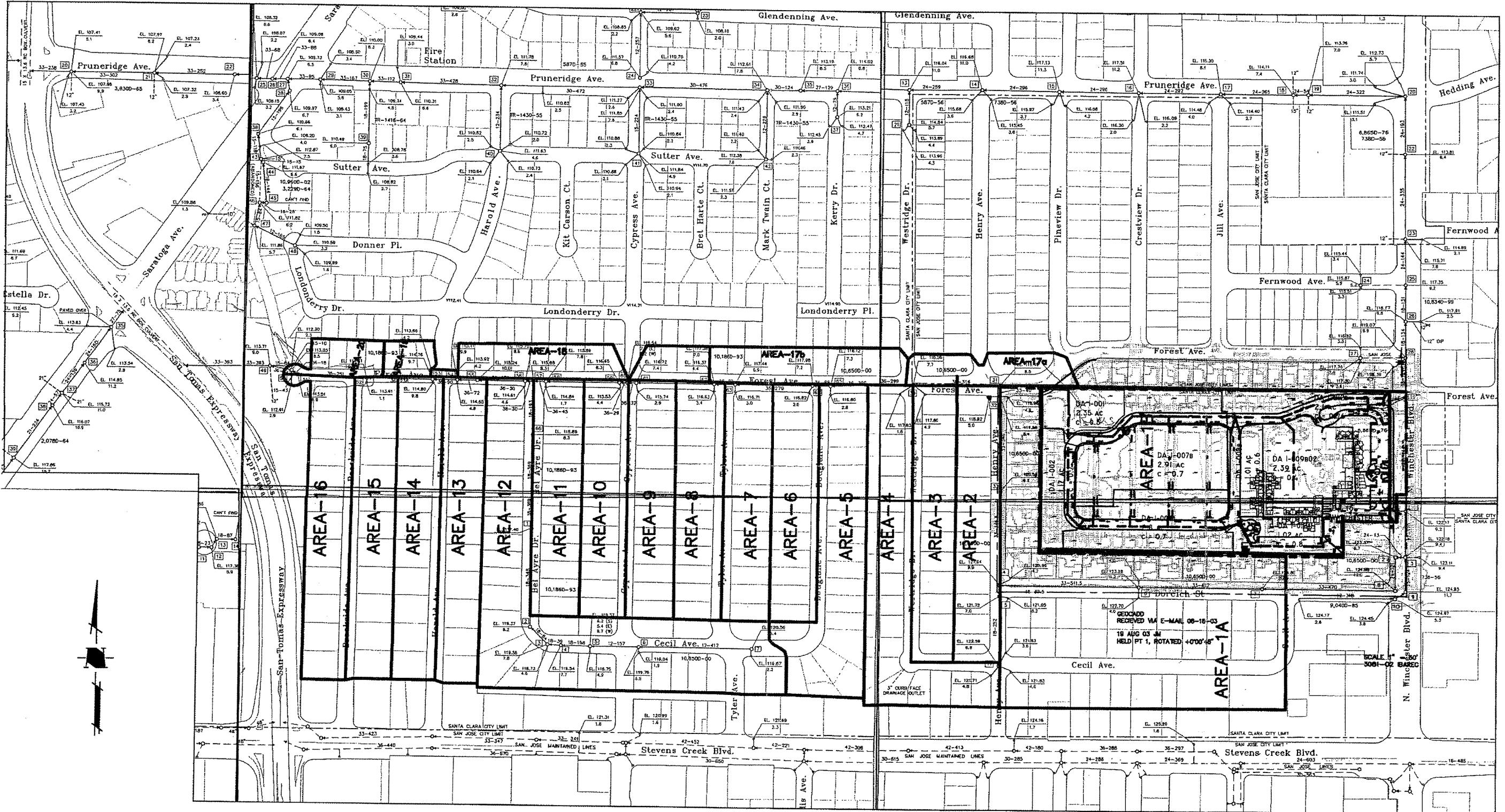
Equivalent Area $\rightarrow (0.3)(5.79) = (0.67)(x) \rightarrow x = 2.59$ ac

Minimum Area to Drain to Winchester Boulevard Based on Best Engineering Design \rightarrow
0.82 ac

Part II (Part of Site Draining to Forest Avenue)

Total Site Area to Drain to Forest Avenue = $16.56 - 0.82 = 15.74$ ac

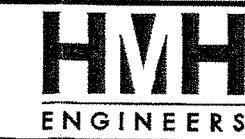




Proposed Development Area 16.56 AC

BY DATE	REVISIONS

Date: 1/31/06
Scale: 1" = 180'
Designed:
Drawn: JH/CS
Checked: LK
Proj. Engr:
File: 3081_SD_area

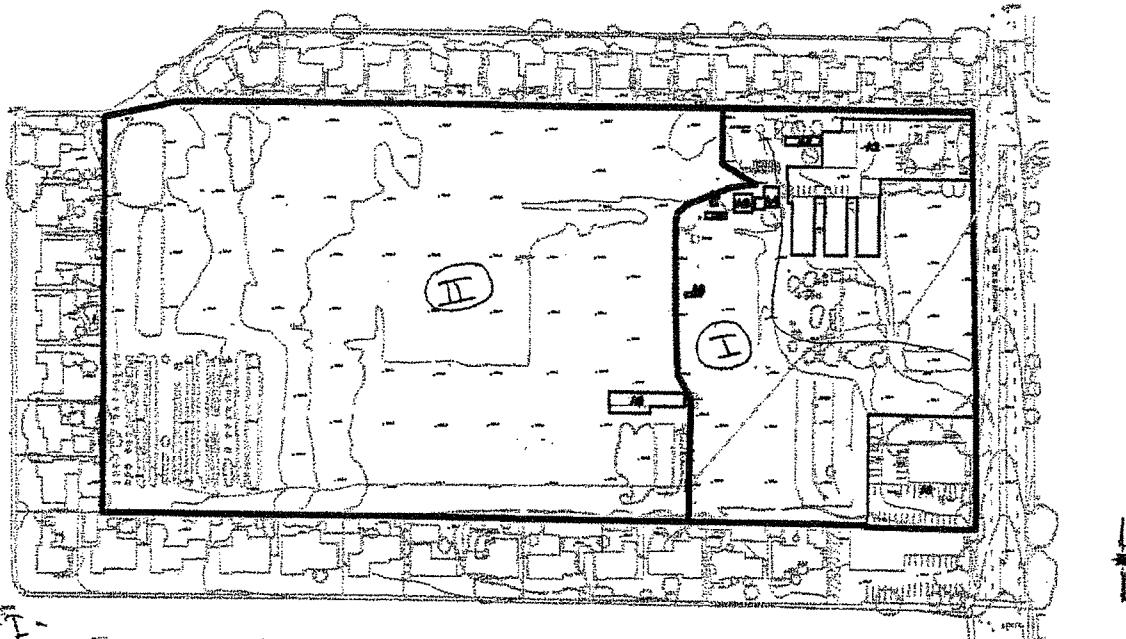


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BAREC Site Development Project
Onsite and Offsite Drainage Areas

Sheet
1
of 1 Sheets
JOB NUMBER
3081.02

EXISTING CONDITIONS



Part I -

Impervious Area in Part I (towards Winchester B)

$$\begin{aligned}
 &= 27123 \cdot A_1 + 32145 \cdot A_2 + 613 \cdot A_3 + 829 \cdot A_4 + 693 \cdot A_5 + 269 \cdot A_6 + 50 \cdot A_7 \\
 &\quad + 142 \cdot A_8 \\
 &= 61874 \text{ SF} = \underline{1.42 \text{ Ac}}
 \end{aligned}$$

Porous Area in Part I

$$\begin{aligned}
 &= \text{Total Area of part I} - \text{Impervious Area} \\
 &= 252374 \text{ SF } (5.79 \text{ Ac}) - 1.42 \text{ Ac} \\
 &= \underline{4.37 \text{ Ac}}
 \end{aligned}$$

Part II Total Property Area - Part I Area

$$= 16.56 \text{ Ac} - 5.79 \text{ Ac} = \underline{10.77 \text{ Ac}}$$

Impervious Area in Part II = 2704 SF

$$= \underline{0.062 \text{ Ac}}$$

$$\text{Porous area} = 10.77 - 0.062 = \underline{10.71 \text{ Ac}}$$

Runoff coefficients

Part I (Table - 5)

Impervious area 1.42 Ac $C = 0.9$

Porous area 4.37 Ac $C = 0.15$

$$\text{Weighted } C = \frac{1.42 \times 0.90 + 4.37 \times 0.15}{4.37 + 1.42}$$
$$= 0.33$$

Part II

Impervious area = 0.062 Ac, $C = 0.9$

Porous area 11.828 Ac, $C = 0.15$

$$\text{Weighted } C = \frac{11.828 \times 0.15 + 0.062 \times 0.90}{11.828 + 0.062}$$
$$= 0.154$$

TABLE 14.7 Runoff Coefficients & Recurrence Interval ≤ 10 years*

DESCRIPTION OF AREA	RUNOFF COEFFICIENTS	CHARACTER OF SURFACE	RUNOFF COEFFICIENTS
Business		Pavement	
Downtown	0.70–0.95	Asphalt or concrete	0.70–0.95
Neighborhood	0.50–0.70	Brick	0.70–0.85
Existing Residential Developments <i>C = 0.4</i>		Roofs	0.70–0.95
Single-family	0.30–0.50	Lawns, sandy soil	
Multifamily, detached	0.40–0.60	Flat, 2%	0.05–0.10
Multifamily, attached	0.60–0.75	Average, 2–7%	0.10–0.15
Residential, suburban	0.25–0.40	Steep, 7% or more	0.15–0.20
Apartment	0.50–0.70		
Industrial		Lawns, heavy soil	
Light	0.50–0.80	Flat, 2%	0.13–0.17
Heavy	0.60–0.90	Average, 2–7%	0.18–0.22
Parks, cemeteries	0.10–0.25	Steep, 7% or more	0.25–0.35
Railroad yard	0.20–0.35		
Unimproved	0.10–0.30		

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intensity storms are the cause of flooding. For such short-duration storms and small drainage areas, the rainfall intensity is assumed constant and the peak runoff rate occurs when the entire drainage area is contributing to the runoff—that is, when the runoff from the drainage area is in steady-state equilibrium. Therefore, for peak runoff to occur the time interval of the constant rainfall intensity must, as a minimum, be equal to the time of concentration of the catchment. If a storm of constant intensity begins instantaneously, the runoff rate steadily increases until the entire drainage area is contributing to the discharge at the outlet point. From then on the drainage area is in equilibrium. All precipitation is converted to runoff, and the peak runoff remains uniform for the duration of the constant-intensity rainfall.

Peak runoff from the rational method is given by

$$Q_p = ACi \quad (14.12)$$

where Q_p is the peak discharge in cfs, A is the drainage area in acres, C is a runoff coefficient characteristic of the ground surface ($0 < C < 1$), and i is the averaged rainfall intensity in in/hr. The precision of the peak discharge depends on the estimated values of C and i . Recognize that the averaged rainfall intensity is a function of the time of concentration of the drainage area.

Runoff Coefficient

In equation (14.12) the product iA can be considered as the inflow to the catchment, which is also the maximum possible runoff rate. The ratio of peak discharge, Q_p , to inflow, iA , is

the runoff coefficient, C . It can be considered as a lump sum parameter that accounts for abstractions, antecedent moisture conditions, and other variables affecting the runoff rate. Table 14.7 identifies ASCE's version of the runoff coefficient, and the standards used in Austin, Texas, are shown in Table 14.8. Note that the C coefficient is also a function of the storm recurrence interval.

SCS methodology for hydrologic modeling (TR-55) classifies soil series into four hydrologic groups (A, B, C, D) according to soil infiltration and permeability characteristics. Soils in group A have the highest infiltration rates, that is, the lowest runoff potential, and group D soils have the highest runoff potential. Table 14.9 correlates the C coefficient to hydrologic soil groups and slope ranges with various types of land use.

Whenever a single catchment area consists of several areas with different C coefficients, a weighted coefficient is computed. The weighted coefficient is found by

$$C_w = \frac{\sum_{i=1}^n C_i A_i}{A_T} \quad (14.13)$$

where C_w is the weighted C coefficient, A_i is the area of the subarea with C_i coefficient, and A_T is the total area of the catchment.

Time of Concentration

The time of concentration is the time for water to flow from the most hydraulically remote point of the drainage area to the outlet point. Recognize that this does not imply the most

Table 5 *

Runoff Coefficients for Urban Areas

<u>Class of Area</u>		<u>Coefficient</u>	
<u>Streets</u>			
Asphalt		0.70 - 0.95	(Note 1)
<u>Concrete</u>		0.80 - 0.95	(Note 1) G-9
Driveways and Walks		0.75 - 0.85	(Note 1)
Roofs		0.75 - 0.95	(Note 2)
<u>Lawns, parks, cemeteries, and unimproved areas</u>			
Sandy Soil	slope < 2%	0.05 - 0.10	(Note 3)
Sandy Soil	2% < slope < 7%	0.10 - 0.15	(Note 3)
Sandy Soil	7% < slope	0.15 - 0.20	(Note 3)
<u>Heavy Soil</u>	<u>slope < 2%</u>	0.13 - 0.17	(Note 3)
Heavy Soil	2% < slope < 7%	0.18 - 0.22	(Note 3)
Heavy Soil	7% < slope	0.25 - 0.35	(Note 3)

Note 1) Larger values generally apply to pavement in good condition.

Note 2) Larger values apply where lots are small or roof drains discharge onto walks, driveways, or other impervious areas.

Note 3) Larger values generally apply unless surface is uneven and many puddles form.

* Design and construction of sanitary and storm sewers, ASCE Manual of Engineering Practice No. 37, 1960.

BAREC DEVELOPMENT SITE

TIME OF CONCENTRATION

PRE-DEVELOPMENT

Part I (draining to Winchester Boulevard)

Total length = 856 ft

H = 124.8 - 120 = 4.8 ft

$$T_c = 0.0078 \left[\frac{856^{\frac{3}{2}}}{4.8^{\frac{1}{2}}} \right]^{0.77} = 10.39 \text{ min}$$

Part II (draining to Forest Avenue)

Total length = 1346 ft

H = 124.8 - 120.5 = 4.3 ft

$$T_c = 0.0078 \left[\frac{1346^{\frac{3}{2}}}{4.3^{\frac{1}{2}}} \right]^{0.77} = 18.29 \text{ min}$$

POST-DEVELOPMENT

Part II (draining to Forest Avenue)

Storm CAD T_c is approximately 23.4 minutes

BAREC On-Site Drainage Areas and Times of Concentration

BAREC Site
Proposed Drainage Areas, C factors, and Initial Time of Concentration Calculation

slope	Invert	Pipe Length	DA (ac)	Imperv area	% Imperv	C	Type of flow	Distance feet	Qinitial cfs	15*C*A V ft/s	Tc add min	Tc total min
upstream												
J-000	111.12	243	2.35	46027	102461	0.45	0.5	gutter	540	3.28	2.42	8.72
J-001	111.85	156	1.17	3903	5406	0.72	0.7	gutter	235	2.29	2.21	6.77
J-002	112.32	166										
J-003b	112.82											
J-004b	112.95	45										
J-005b	113.13	60										
J-006b	113.54	135										
J-007b	113.96	140	2.91	1388	20694	0.67	0.7	gutter	228	5.68	2.78	6.37
J-008b	114.26	103	1.01	24868	44106	0.56	0.6	gutter	320	1.69	2.05	7.60
J-009b	114.77	170										
J-010b	115.36	195										
J-011b	115.74	128										
J-012b	115.90	52	2.10	21725	91581	0.76	0.76	gutter	525	4.46	2.77	3.16
J-009b01	114.97	65										
J-009b02	115.60	209	2.39	69846	104309	0.33	0.4	Pipe	141	2.48	0.95	5.95
J-003	113.19	281										
J-004	113.38	63										
J-005	113.54	52										
J-006	113.94	136										
J-007	114.36	140										
J-008	114.77	137	2.80				0.7	gutter	520	5.47	2.75	3.15
J-009	114.97	65										
J-010	115.17	66										
J-011	115.44	91										
J-012	116.22	259	1.02	7338	44599	0.84	0.8	sheet flow	260			5.1
DA to Winchester						Average C	0.63					
						0.82						
						16.59	check					

1/31/2006

3081-DA onsite.xls

Tc Derivation for Upstream Node I-012b

Project Description

Solve For Spread

Input Data

Channel Slope	0.00560 ft/ft
Discharge	4.46 ft³/s
Gutter Width	19.70 ft
Gutter Cross Slope	0.03 ft/ft
Road Cross Slope	0.02 ft/ft
Roughness Coefficient	0.013

Results

Spread	11.35 ft
Flow Area	1.61 ft²
Depth	0.28 ft
Gutter Depression	0.10 ft
Velocity	2.77 ft/s

Gutter Flow for DA I-05 from South

Project Description

Solve For Spread

Input Data

Channel Slope	0.00480	ft/ft
Discharge	2.29	ft³/s
Gutter Width	19.70	ft
Gutter Cross Slope	0.03	ft/ft
Road Cross Slope	0.02	ft/ft
Roughness Coefficient	0.013	

Results

Spread	9.10	ft
Flow Area	1.03	ft²
Depth	0.23	ft
Gutter Depression	0.10	ft
Velocity	2.21	ft/s

The logo consists of the letters "HMH" in a large, bold, black font, with "ENGINEERS" in a smaller, bold, black font underneath.

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t :

$$T_t = \frac{0.007 (nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \quad [\text{Eq. 3-3}]$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n^1
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover $\leq 20\%$	0.06
Residue cover $> 20\%$	0.17
Grass:	
Short grass prairie	0.15
Dense grasses ²	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods: ³	
Light underbrush	0.40
Dense underbrush	0.80

¹The n values are a composite of information compiled by Engman (1986).

²Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

³When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
 n = Manning's roughness coefficient (table 3-1),
 L = flow length (ft),
 P_2 = 2-year, 24-hour rainfall (in), and
 s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

BAREC DEVELOPMENT SITE

OFF-SITE TIMES OF CONCENTRATION (1 OF 2)

EXISTING-DEVELOPMENT

From gutter slope table

Slope	Gutter Velocity (fps)
0.002	1.4
0.003	1.65 (average)
0.004	1.9

Assumptions

Slope of approximately 0.003

Roof-to-gutter time = 5 minutes

Westridge Avenue

L = 930'

Gutter flow time = $930/1.65/60 = 9.4 \text{ min}$

$T_c = 5 + 9.4 \text{ min} = 14.4 \text{ min}$

Douglane Avenue, Tyler Avenue, Cypress Avenue

L = 900'

Gutter flow time = $900/1.65/60 = 9.1 \text{ min}$

Bel Ayre Avenue

L = 1710'

Assume pipe is flowing full

12" Pipe flow time:

$$V = 1.486/n*R^{2/3}S^{1/2}$$

$$R = A/P = \pi r^2/(2\pi r) = r/2 = d/4$$

$$S_{12''} = ((119.87-2.2=117.67) - (118.75-4.9=113.85))/569' = 0.0067$$

$$V_{12''} = 1.486/0.013*(1/4)^{2/3}(0.0067)^{1/2} = 3.71 \text{ fps}$$

$$T_{12''} = 569/3.71/60 = 2.56 \text{ min}$$

$$S_{18''} = ((118.75-4.9=113.85) - (115.68-8.3=107.38))/1191' = 0.0054$$

$$V_{18''} = 1.486/0.013*(1.5/4)^{2/3}(0.0054)^{1/2} = 4.37 \text{ fps}$$

$$T_{18''} = 1191/4.37/60 = 4.54 \text{ min}$$

$$T_c = 5 + 2.56 + 4.54 \text{ min} = 12.1 \text{ min}$$

However:

Bel Ayre Avenue Gutter flow time for 910' of the street:

$$910'/1.65/60 = 9.2 \text{ min}$$

$$T_c = 5 + 9.2 \text{ min} = 14.2 \text{ min}$$

This is the value used in the model.

BAREC DEVELOPMENT SITE

OFF-SITE TIMES OF CONCENTRATION, CONTINUED (2 OF 2)

Harold Avenue, Brookside Avenue

$$L = 1070'$$

$$\text{Gutter flow time} = 1070/1.65/60 = 10.8 \text{ min}$$

$$T_c = 5 + 10.8 \text{ min} = 15.8 \text{ min}$$

Henry Avenue, Dorcich Street

$$L = 2126'$$

Pipe flow time:

$$V = 1.486/n*R^{2/3}S^{1/2}$$

$$S_{33''} = ((124.98 - 12 = 112.98) - (119.58 - 8.4 = 111.18))/2126' = 0.000847$$

$$V_{33''} = 1.486/0.013*(2.75/4)^{2/3}(0.00085)^{1/2} = 2.6 \text{ fps}$$

$$T_{33''} = 2126/2.6/60 = 13.6 \text{ min}$$

$$T_c = 5 + 13.6 \text{ min} = 18.6 \text{ min}$$

However:

With no inlets on the side for 915', the gutter flow time is:

$$915/1.65/60 = 9.24 \text{ min}$$

$$T_c = 5 + 9.24 \text{ min} = 14.24 \text{ min}$$

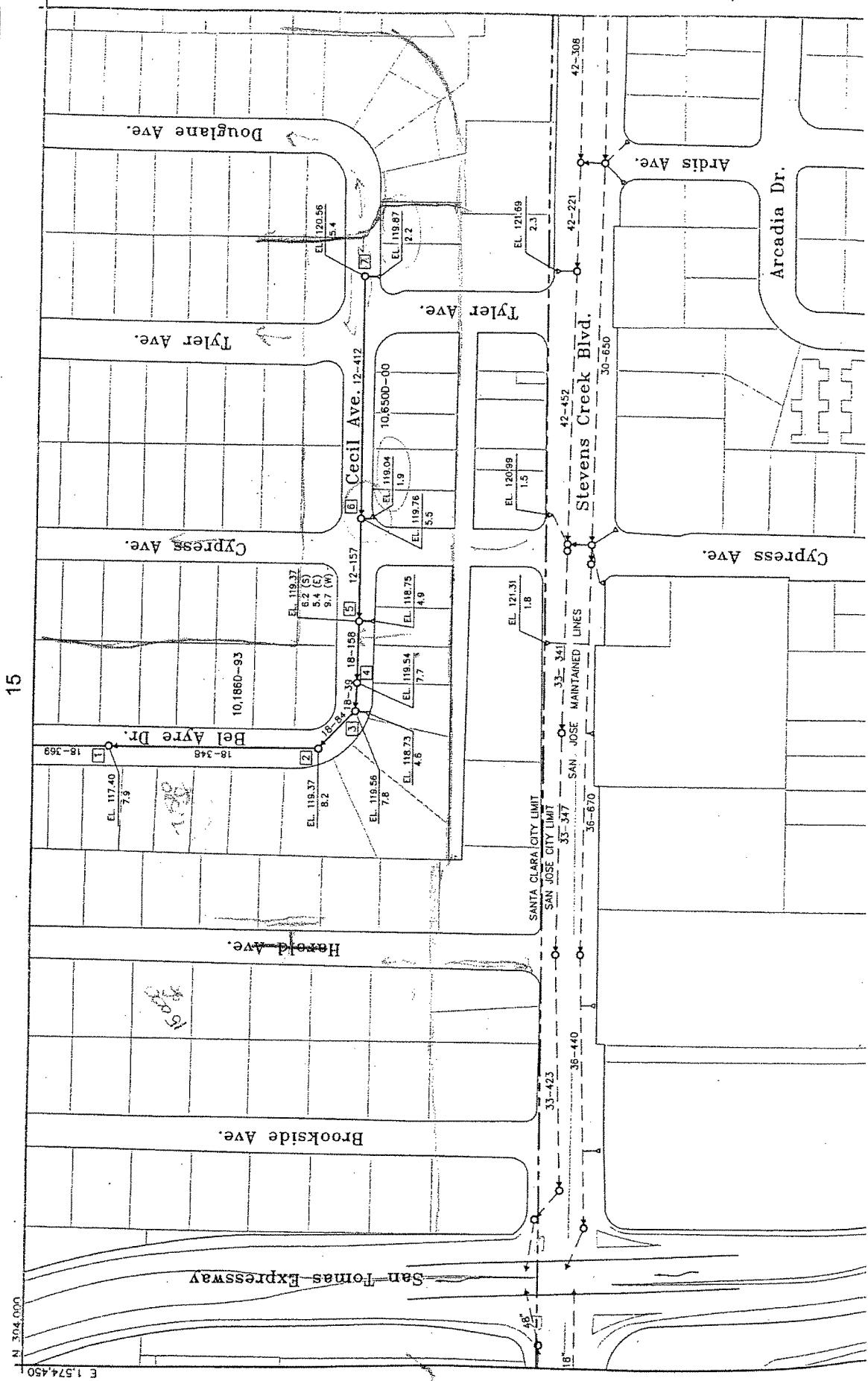
This is the value used in the model

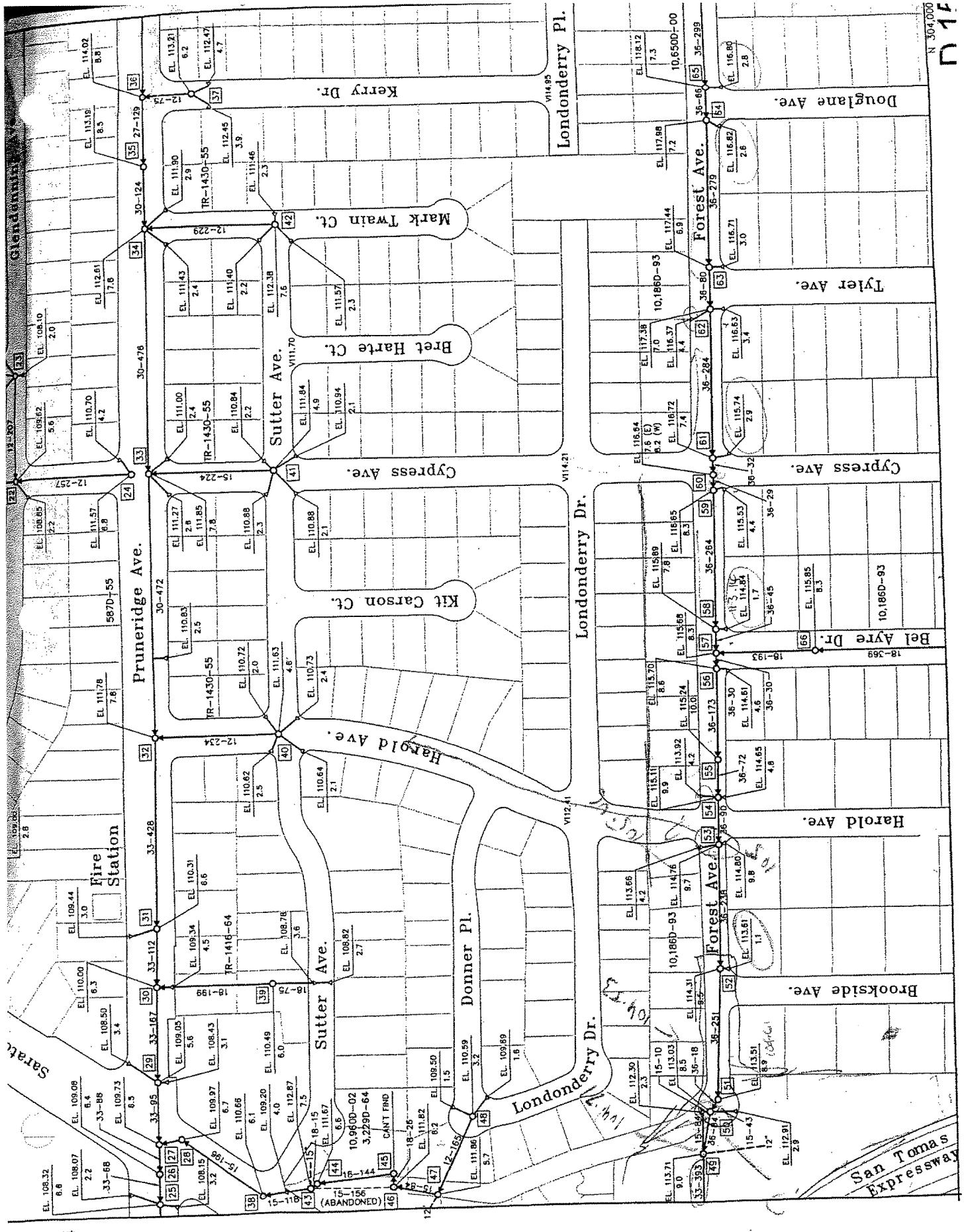
Bel Aire SD System

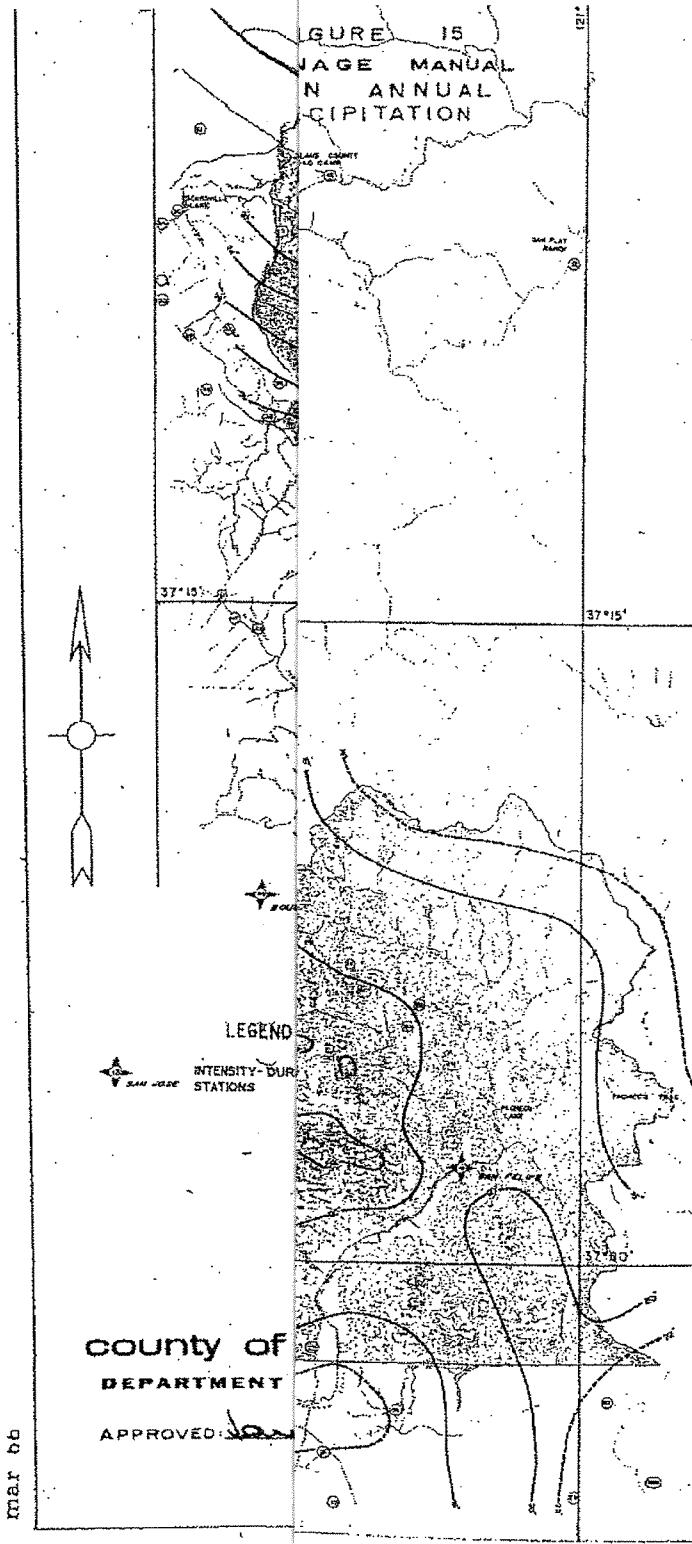
CITY OF SANTA CLARA BASIC INFORMATION MAP

SCALE (NOTE: REDUCED ON 11X17 PAGES)
100 90 80 70 60 50 40 30 20 10 0 500 FT.

DATE LAST CORRECTED
MAP NO.
5
08-12-02 []







BAREC DEVELOPMENT SITE

I-D-F EQUATION FOR 10-YEAR RETURN EVENT

$$I = \frac{K}{T_c^n} \rightarrow \log(I) = \log(K) - n \log(T)$$

Mean Annual Precipitation For Site = 14.7 (Figure 15, Santa Clara County Drainage Manual)

Method 1

Mean Annual Precipitation Baseline For San Jose = 13.1 (Figure 6, Drainage Manual)

10-Year Return:	$I_{60\text{ min}}$	$I_{10\text{ min}}$	Units
	0.59	1.8	in/hr

Intensities Adjusted for MAP = 14.7

$$I_{60\text{ min}} = 0.59 \times (14.7/13.1) = 0.662$$

$$I_{10\text{ min}} = 1.8 \times (14.7/13.1) = 2.02$$

$$\text{Eqn. 1. } \log(0.662) = \log(K) - n \log(60/60)$$

$$\text{Eqn. 2. } \log(2.02) = \log(K) - n \log(10/60)$$

Solving for Eqn. 1:

$$K = 0.662$$

Solving for Eqn. 2:

$$n \log(10/60) = \log(0.662) - \log(2.02) = -0.4845$$

$$n = 0.622$$

Method 2

Using Figure 14 (Drainage Manual):

$$K = 0.675$$

$$n = 0.52$$

Averaging the Two Methods

$$K = \frac{0.662 + 0.675}{2} = 0.669$$

$$n = \frac{0.622 + 0.52}{2} = 0.6$$

BAREC DEVELOPMENT SITE

I-D-F EQUATION FOR 5-YEAR RETURN EVENT

$$I = \frac{K}{T_c^n} \rightarrow \log(I) = \log(K) - n \log(T)$$

Mean Annual Precipitation For Site = 14.7 (Figure 15, Santa Clara County Drainage Manual)

Method 1

Mean Annual Precipitation Baseline For San Jose = 13.1 (Figure 6, Drainage Manual)

10-Year Return:	$I_{60\text{ min}}$	$I_{10\text{ min}}$	Units
	0.52	1.55	in/hr

Intensities Adjusted for MAP = 14.7

$$I_{60\text{ min}} = 0.52 \times (14.7/13.1) = 0.584$$

$$I_{10\text{ min}} = 1.55 \times (14.7/13.1) = 1.74$$

$$\text{Eqn. 1. } \log(0.584) = \log(K) - n \log(60/60)$$

$$\text{Eqn. 2. } \log(1.74) = \log(K) - n \log(10/60)$$

Solving for Eqn. 1:

$$K = 0.584$$

Solving for Eqn. 2:

$$n \log(10/60) = \log(0.584) - \log(1.74) = -0.474$$

$$n = 0.61$$

Method 2

Using Figure 14 (Drainage Manual):

$$K = 0.58$$

$$n = 0.525$$

Averaging the Two Methods

$$K = \frac{0.584 + 0.58}{2} = 0.582$$

since $n = 0.61$ is very high (according to Figure 14, this value is never achieved), the value of Method 2 was chosen:

$$n = 0.53$$

BAREC DEVELOPMENT SITE

I-D-F EQUATION FOR 3-YEAR RETURN EVENT

$$I = \frac{K}{T_c^n} \rightarrow \log(I) = \log(K) - n \log(T)$$

Mean Annual Precipitation For Site = 14.7 (Figure 15, Santa Clara County Drainage Manual)

Method 1

Mean Annual Precipitation Baseline For San Jose = 13.1 (Figure 6, Drainage Manual)

10-Year Return:	$I_{60 \text{ min}}$	$I_{10 \text{ min}}$	Units
	0.48	1.3	in/hr

Intensities Adjusted for MAP = 14.7

$$\begin{aligned} I_{60 \text{ min}} &= 0.48 \times (14.7/13.1) = 0.539 \\ I_{10 \text{ min}} &= 1.3 \times (14.7/13.1) = 1.46 \end{aligned}$$

$$\text{Eqn. 1. } \log(0.539) = \log(K) - n \log(60/60)$$

$$\text{Eqn. 2. } \log(1.46) = \log(K) - n \log(10/60)$$

Solving for Eqn. 1:

$$K = 0.539$$

Solving for Eqn. 2:

$$n \log(10/60) = \log(0.539) - \log(1.46) = -0.433$$

$$n = 0.56$$

Method 2

Using Figure 14 (Drainage Manual):

$$K = 0.49$$

$$n = 0.52$$

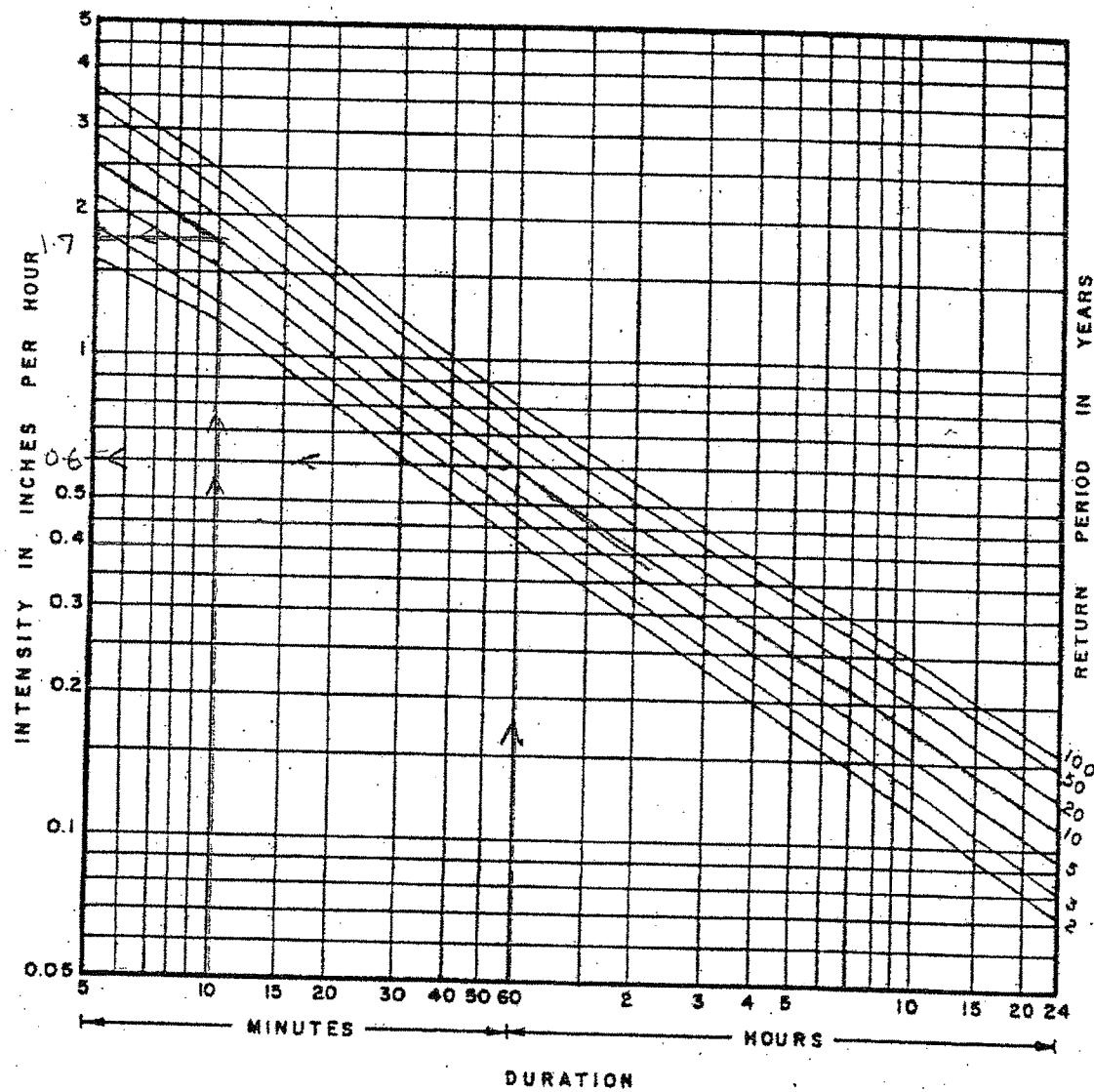
Averaging the Two Methods

$$K = \frac{0.539 + 0.49}{2} = 0.515$$

$$n = \frac{0.56 + 0.52}{2} = 0.54$$

county of santa clara
DEPARTMENT OF PUBLIC WORKS
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DIRECTOR

FIGURE 6
DRAINAGE MANUAL
PRECIPITATION
INTENSITY-DURATION-FREQUENCY
SAN JOSE



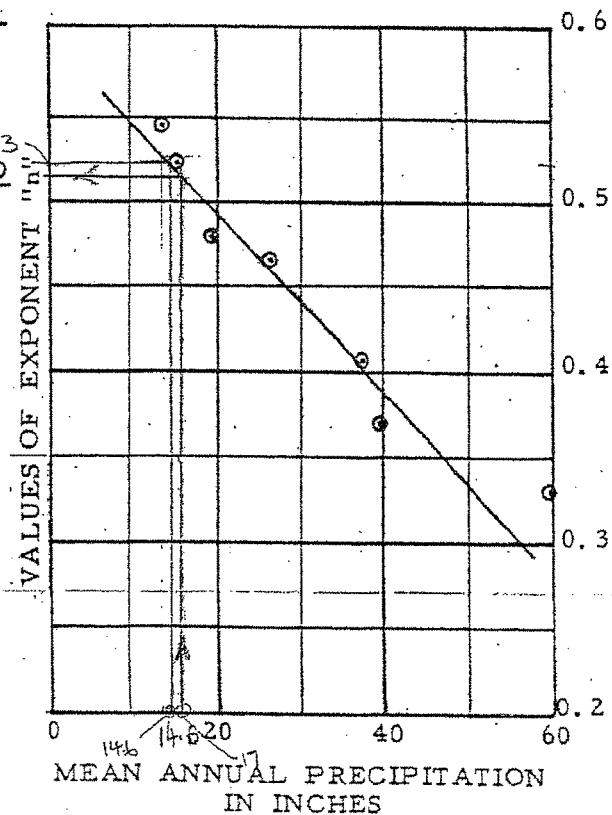
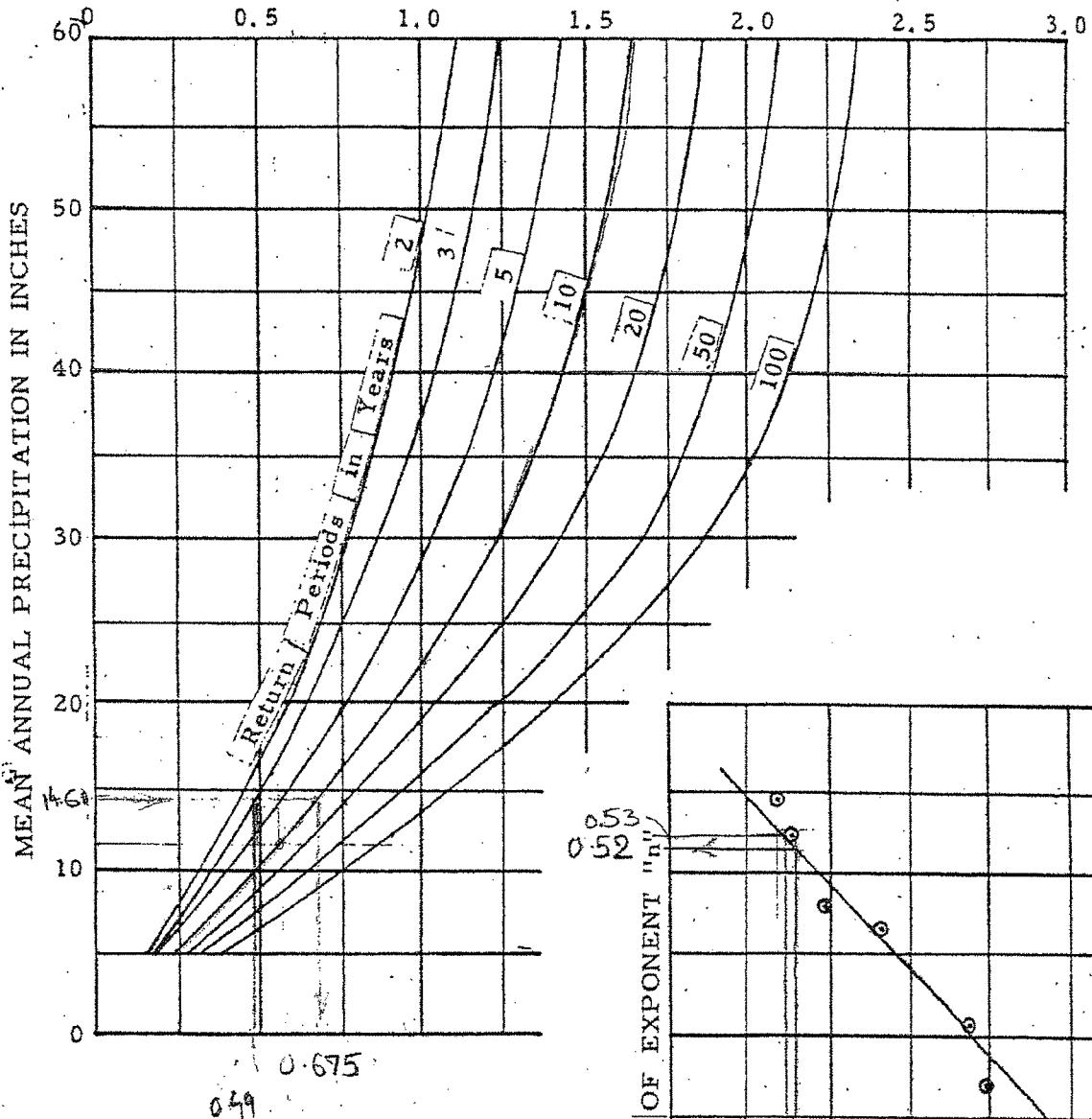
STATION NO. 782100
ADJUSTED MEAN ANNUAL PRECIPITATION 131 INCHES
1918 - 1961

COUNTY OF SANTA CLARA
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FIGURE 14
DRAINAGE MANUAL
PRECIPITATION
INTENSITY - DURATION - FREQUENCY
REGIONAL CONSTANTS

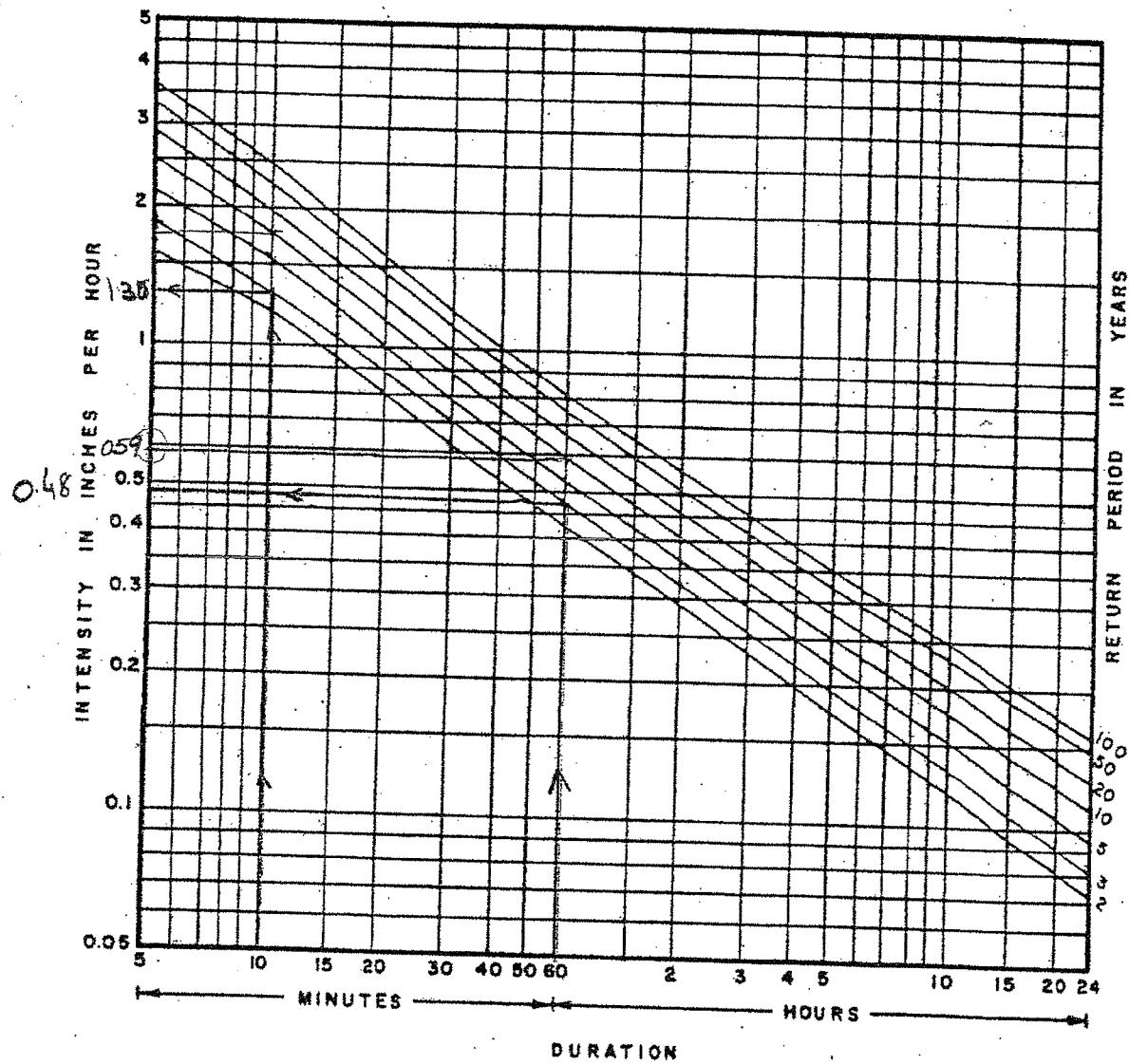
VALUES OF REGIONAL CONSTANT "K"



COUNTY OF SANTA CLARA
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FIGURE (6)
DRAINAGE MANUAL
PRECIPITATION
INTENSITY-DURATION-FREQUENCY
SAN JOSE

3 yr event

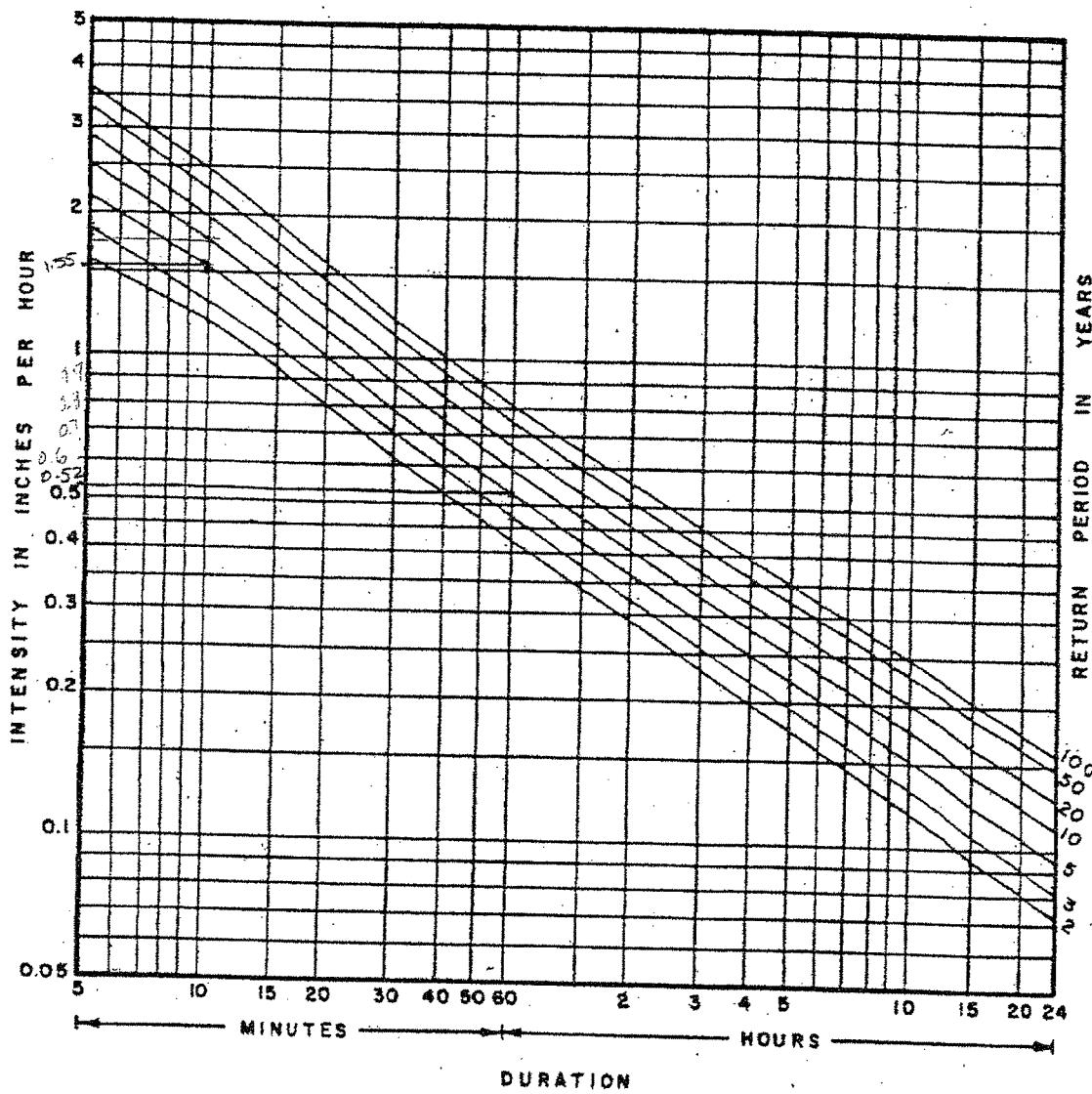


STATION NO. 782100
ADJUSTED MEAN ANNUAL PRECIPITATION 13.1 INCHES
1918 - 1961

COUNTY OF SANTA CLARA
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FIGURE 6
DRAINAGE MANUAL
PRECIPITATION
INTENSITY - DURATION - FREQUENCY
SAN JOSE

5 yr event

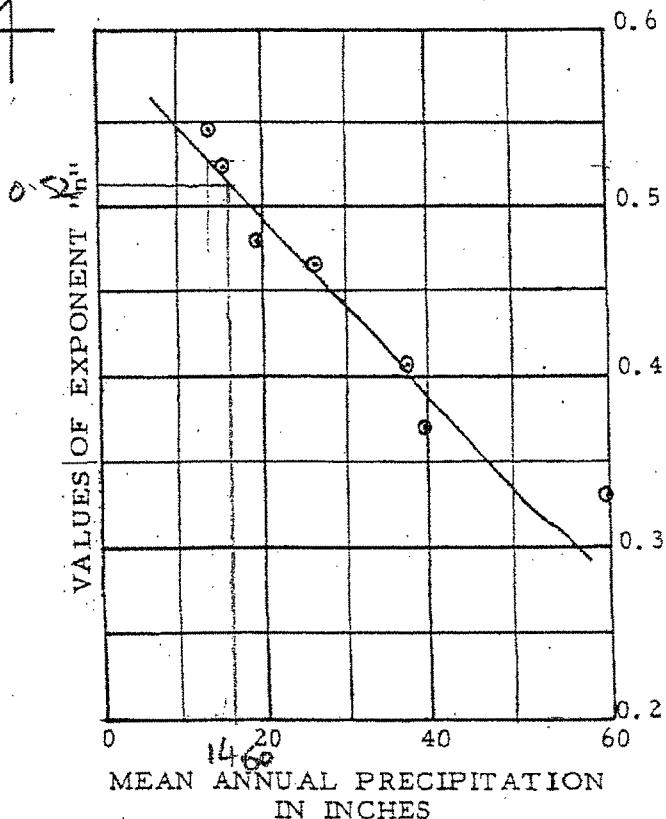
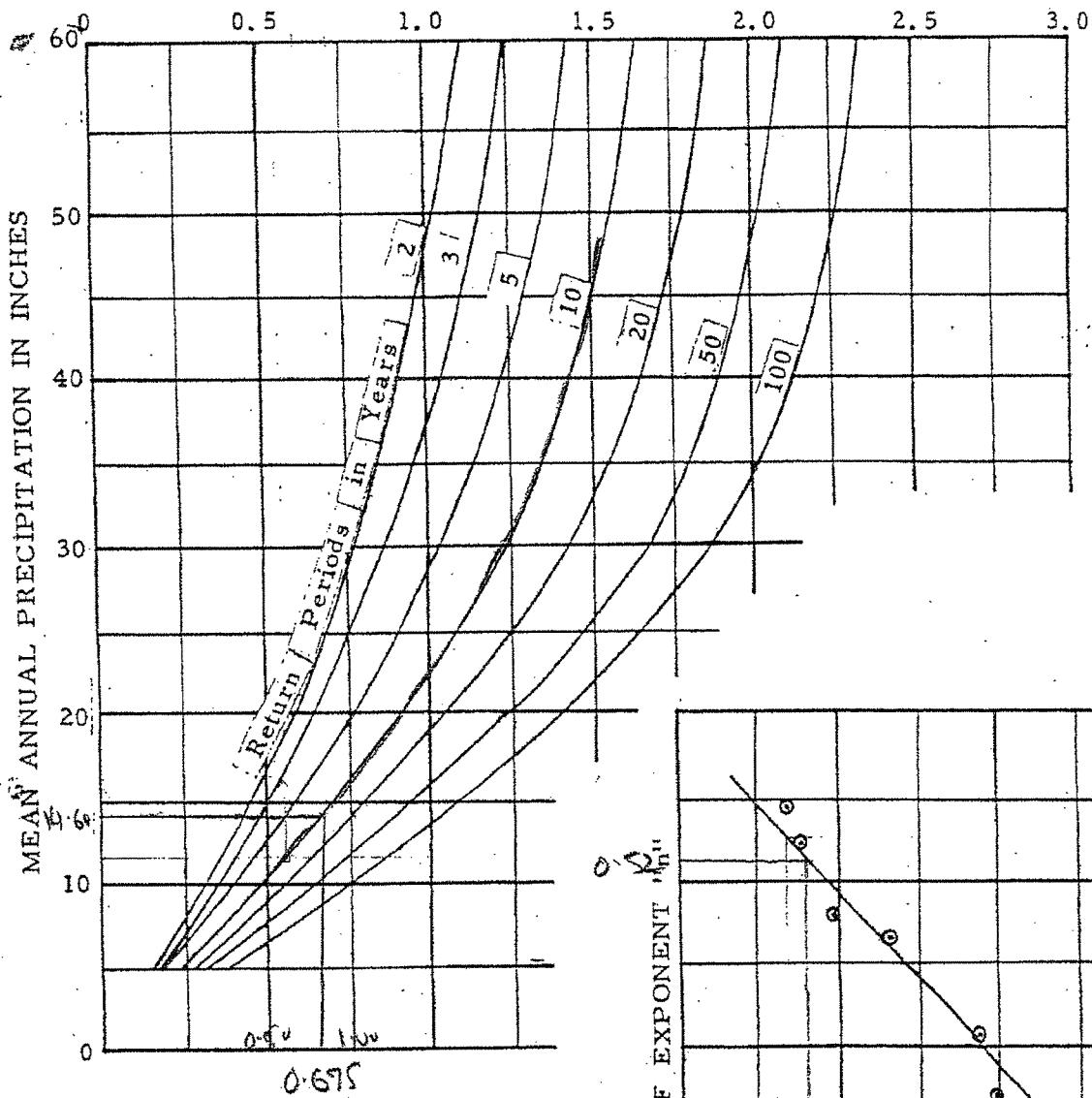


STATION NO. 782100
ADJUSTED MEAN ANNUAL PRECIPITATION 131 INCHES
1918 - 1961

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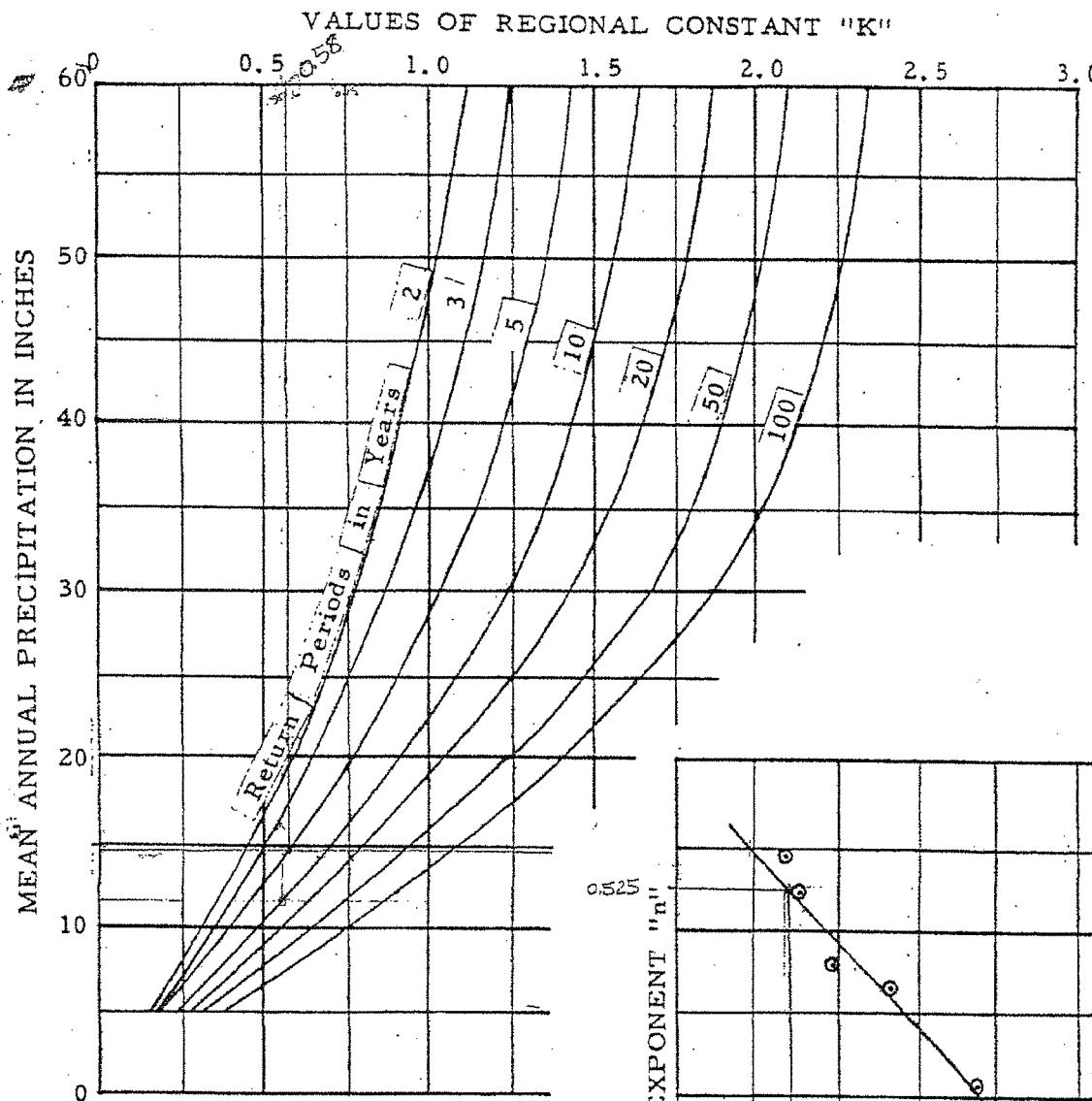
FIGURE 14
DRAINAGE MANUAL
PRECIPITATION
INTENSITY-DURATION-FREQUENCY
REGIONAL CONSTANTS

VALUES OF REGIONAL CONSTANT "K"

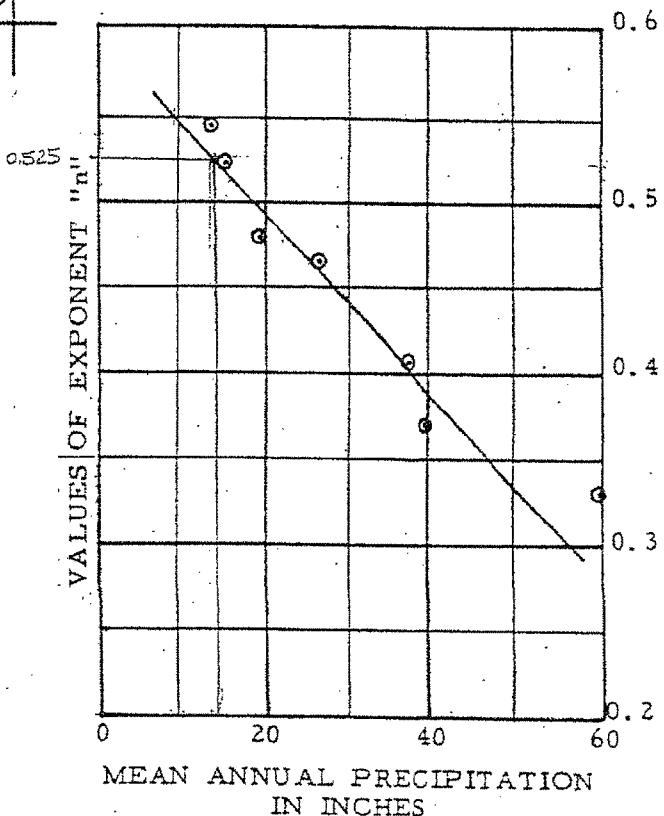


county of santa clara
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FIGURE 14
DRAINAGE MANUAL
PRECIPITATION
INTENSITY - DURATION - FREQUENCY
REGIONAL CONSTANTS



5yr return period



3.0 DEFINITION OF DESIGN FLOW

The design flow is the maximum flow which a structure or system of structures is expected to pass without surcharging and flooding of streets, damaging property, or injuring persons. The design flow is usually expressed as a peak rate of flow. Under circumstances in which storage of all or part of the flow occurs within or upstream of the project, the design flow must also be defined by a complete flood hydrograph in order that volume of flow can be considered.

4.0 STANDARD OF DESIGN

The standard of design is expressed as the return period of the design flow. Return period is the average interval of time between the occurrence of flows of a given magnitude or greater. The term "return period", symbolized by t_r , does not imply that floods will occur at regular intervals, but rather, that for a sufficiently long period of N years, one might expect approximately N/t_r occurrences of flow equal to or greater than the design flow.

The following return periods are considered the minimum acceptable within Santa Clara County.

<u>Drainage Area Tributary to Structure</u>	<u>Minimum Return Period</u>
200 acres or less	3 years
Between 200 and 2560 acres	10 years
Over 2560 acres	25 years

Where feasible, the design of a project should be related to project costs and benefits, as stated in Section 1.2. Proposals for projects with design return periods less than those given above will be considered only when supported by clear evidence that economic considerations warrant such reduced standards. In some instances, the economic consequences of project failure will be such that the return periods used in design should be greater than those cited above. In such cases, the designer should select the proper return period on the basis of economic analysis and submit this analysis with his request for approval. In all cases it must be shown that the proposed return period will provide adequate protection.

Table 1
BAREC Site
Forest Avenue Storm Drainage System - Existing Conditions
10-year Storm Event
Storm CAD results - Nodes with HEC-22 Method Minor Losses

Label	Area (acres)	Inlet C	Inlet CA (acres)	System Concentration (min)	Time of System Flow (min)	System Intensity (in/hr)	Total System Flow (cfs)	Rim Elevation (ft)	Grade Line In (ft)	Grade Line Out (ft)	Hydraulic Freeboard	Velocity Out (ft/s)	
I-2	3.67	0.4	1.47	1.5	14.24	14.2	1.59	2.4	119.68	114.99	4.69	3.9	
I-1	26.47	0.3	7.9	7.9	18.3	18.3	1.36	10.9	119.62	115	4.62	5.6	
J-1	0	0	9.4	0	18.3	1.36	12.9	119.67	113.44	6.23	2.5		
J-000	0	0	9.4	0	18.5	1.35	12.8	119.56	113.42	6.14	2.2		
I-4	5.58	0.4	2.23	2.2	14.4	14.4	1.38	3.5	118.56	117.16	1.4	5.2	
I-3	3.62	0.4	1.45	1.5	14.4	14.4	1.58	2.3	118.62	114.37	4.25	4.3	
J-18	0	0	13.0	0	20.6	12.7	16.7	118.64	113.29	5.35	2.8		
I-5	5.27	0.4	2.11	2.1	14.1	14.1	1.6	3.4	117.63	114.92	2.71	5.1	
J-17	0	0	15.2	0	22.7	1.2	18.3	118.22	113.03	5.19	3.5		
I-6	3.36	0.4	1.34	1.3	14.1	14.1	1.6	2.2	117.65	114.88	2.77	4.2	
J-16	0	0	16.5	0	23.1	1.19	19.7	118.07	112.94	5.13	3.8		
I-7	3.53	0.4	1.41	1.4	14.1	14.1	1.6	2.3	117.53	114.47	3.06	4.2	
J-15	0	0	17.9	0	24.6	1.14	20.6	117.53	112.36	5.17	5.0		
I-8	3.47	0.4	1.39	1.4	14.4	14.4	1.58	2.2	117.43	113.96	3.47	4.2	
I-17	3.68	0.4	1.47	1.5	5	5.0	2.97	4.4	117.16	113.09	4.07	6.0	
J-14	0	0	20.8	0	24.9	1.13	23.8	117.47	112.1	5.37	6.1		
I-9	3.4	0.4	1.36	1.4	14.1	14.1	1.6	2.2	116.52	113.65	2.87	4.2	
J-13	0	0	22.1	0	25.6	1.11	24.9	116.82	110.99	5.83	6.4		
J-12	0	0	22.1	0	25.7	1.11	24.8	116.73	110.79	5.9	4.3		
I-10	3.22	0.4	1.29	1.3	14.1	14.1	1.6	2.1	116.34	111.85	4.49	4.1	
J-11	0	0	23.4	0	26.8	1.11	26.2	116.74	110.75	5.99	4.5		
I-11	3.49	0.4	1.4	1.4	14.2	14.2	1.59	2.2	116.64	113.65	1.99	2.9	
J-10	0	0	24.8	0	27.0	1.08	27.0	115.97	109.83	6.14	6.6		
J-09	0	0	24.8	0	27.1	1.08	27.0	115.77	109.94	5.83	4.4		
I-12	10.04	0.4	4.02	4.0	14.2	14.2	1.59	6.4	115.39	111.16	4.23	8.3	
J-08	0	0	28.8	0	27.1	1.08	31.3	115.78	109.95	5.83	4.6		
J-07	0	0	28.8	0	27.4	1.07	31.1	115.35	109.59	5.76	4.4		
I-18	2.44	0.4	0.98	1.0	5	5.0	2.97	2.9	114.65	110.53	4.12	4.7	
I-13	3.9	0.4	1.56	1.6	15.8	15.8	1.49	2.3	114.76	110.47	4.29	4.3	
J-06	0	0	31.4	0	27.7	1.06	33.6	115.21	109.44	5.77	4.8		
I-14	4.03	0.4	1.61	1.6	15.8	15.8	1.49	2.4	114.97	111.04	3.93	4.0	
I-19	0.53	0.4	0.21	0.2	5	5.0	2.97	0.6	114.68	110.89	3.79	2.7	
J-05	0	0	33.2	0	28.0	1.06	35.4	114.87	109.21	5.66	5.0		
I-15	4	0.4	1.6	1.6	15.8	15.8	1.49	2.4	114.43	113.29	1.14	4.3	
J-04	0	0	34.8	0	28.8	1.04	36.4	114.42	108.54	5.88	5.2		
J-03	0	0	34.8	0	29.6	1.02	35.8	113.61	107.79	5.82	5.1		
I-16	4.12	0.4	1.65	1.7	15.8	15.8	1.49	2.5	113.52	110.82	2.7	3.9	
I-20	0.87	0.4	0.35	0.4	7	7.0	2.43	0.9	112.96	110.57	2.39	2.9	
J-02	0	0	36.8	0	29.7	1.02	37.8	113.15	107.74	5.41	5.4		
J-01	0	0	36.8	0	29.9	1.02	37.7	113.79	107.46	6.33	6.3		
O-1	0	0	36.8	0	31.0	0.99	36.9	111	105.47	105.47	5.53	0.0	

Table 2
BAREC Site
Forest Avenue Storm Drainage System - Existing Conditions
"10-year Storm Event
Storm CAD results - Pipes with HEC-22 Method Minor Losses

Label	Upstream Node	Downstream Node	Length (ft)	Constructed Slope (ft/ft)	Section Size	Manning's n	Full System		Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Hydraulic Grade Line Out (ft)	Hydraulic Grade Line In (ft)	Freeboard		
							Capacity (cfs)	Flow (cfs)							
P-25	J-1	J-1	17	0.0900	24 inch	0.013	67.9	10.9	116.68	113.82	112.29	115	112.96	4.62	
P-26	J-2	J-1	30	0.0403	15 inch	0.013	13.0	2.4	7.72	114.38	113.17	114.99	113.54	4.69	
P-1	J-000	J-18	38	0.0011	33 inch	0.013	17.2	12.9	2.51	111.24	111.24	113.44	113.42	6.23	
P-19	J-000	J-18	316	0.0006	36 inch	0.013	16.4	12.8	2.14	111.12	110.93	113.42	113.29	6.14	
P-27	J-3	J-18	40	0.0153	12 inch	0.013	4.4	2.3	5.66	113.72	113.11	114.37	113.62	4.25	
P-28	J-4	J-18	49	0.0457	12 inch	0.013	7.6	3.5	9.42	116.36	114.12	117.16	114.6	1.4	
P-18	J-18	J-17	298	0.0000	36 inch	0.013	3.9	16.7	3.15	110.93	110.92	113.59	113.03	5.35	
P-29	J-5	J-17	25	0.0368	12 inch	0.013	6.8	3.4	8.06	114.13	113.21	114.82	113.74	2.71	
P-17	J-17	J-16	66	0.0005	36 inch	0.013	14.2	18.3	3.55	110.92	110.89	113.03	112.94	5.19	
P-30	J-6	J-16	26	0.0336	12 inch	0.013	6.6	2.2	7.14	—	114.25	113.37	114.88	113.78	2.77
P-16	J-16	J-15	280	0.0009	36 inch	0.013	6.5	19.7	4.74	110.89	110.95	112.94	112.36	5.13	
P-32	J-7	J-15	23	0.0348	12 inch	0.013	6.6	2.3	7.19	113.83	113.03	114.47	113.45	3.06	
P-15	J-15	J-14	80	0.0023	36 inch	0.013	31.6	20.6	5.26	110.65	110.47	112.36	112.1	5.17	
P-42	J-17	J-14	19	0.0363	12 inch	0.013	6.8	4.4	8.28	112.21	111.52	113.09	112.16	4.07	
P-33	J-8	J-14	23	0.0287	12 inch	0.013	6.0	2.2	6.7	113.33	112.67	113.56	113.11	3.47	
P-14	J-14	J-13	284	0.0038	36 inch	0.013	41.3	23.6	6.16	110.47	108.38	112.1	110.99	5.37	
P-34	J-9	J-13	37	0.0216	12 inch	0.013	5.2	2.2	6.31	113.02	112.22	113.65	112.67	2.87	
P-13	J-13	J-12	32	0.0078	36 inch	0.013	59.0	24.9	6.77	109.38	109.13	110.98	110.79	5.83	
P-12	J-12	J-11	35	0.0026	36 inch	0.013	33.8	24.8	4.25	108.53	108.44	110.78	110.75	5.94	
P-35	J-10	J-11	21	0.0238	12 inch	0.013	5.5	2.1	6.17	111.24	110.74	111.85	111.18	4.49	
P-11	J-11	J-10	258	0.0011	36 inch	0.013	22.4	26.2	6.43	108.44	108.15	110.75	109.83	5.99	
P-36	J-11	J-10	22	-0.0195	12 inch	0.013	-5.0	2.2	4.22	112.34	112.77	113.65	113.41	1.99	
P-10	J-10	J-9	45	0.0140	36 inch	0.013	78.9	27.0	4.43	108.15	107.52	109.83	109.94	6.14	
P-09	J-9	J-8	30	0.0113	36 inch	0.013	71.0	27.0	3.85	107.52	107.18	109.95	109.95	5.83	
P-37	J-12	J-08	21	0.0633	12 inch	0.013	9.0	6.4	8.19	110.19	108.86	111.16	109.95	4.23	
P-08	J-08	J-07	175	0.0102	36 inch	0.013	67.3	31.3	4.43	107.18	105.4	109.56	109.59	5.83	
P-07	J-07	J-06	71	-0.0006	36 inch	0.013	-15.8	31.1	4.4	105.4	105.4	109.59	109.44	5.76	
P-43	J-18	J-06	24	0.0333	12 inch	0.013	9.7	2.9	3.72	108.6	108.04	110.53	109.44	4.12	
P-38	J-13	J-06	17	0.0853	12 inch	0.013	10.4	2.3	2.98	109.81	108.36	110.47	109.44	4.29	
P-06	J-06	J-05	90	0.0030	36 inch	0.013	36.5	33.6	4.78	105.44	105.17	109.21	109.21	5.77	
P-39	J-14	J-05	22	0.1114	15 inch	0.013	21.6	2.4	1.97	110.42	107.97	111.04	109.21	3.93	
P-44	J-19	J-05	25	0.0884	15 inch	0.013	20.3	0.6	0.56	110.58	108.12	110.89	109.21	3.79	
P-05	J-05	J-04	238	0.0006	36 inch	0.013	16.7	35.4	5	105.17	105.32	109.21	108.54	5.66	
P-40	J-15	J-04	18	0.0728	12 inch	0.013	9.6	2.4	9.04	112.63	111.32	113.29	111.69	3.14	
P-04	J-04	J-03	253	0.0014	36 inch	0.013	25.2	36.4	5.15	105.02	104.86	108.54	107.79	5.88	
P-03	J-03	J-02	17	-0.0024	36 inch	0.013	32.4	35.8	5.07	104.66	104.7	107.79	107.74	5.82	
P-45	J-16	J-02	42	0.0052	15 inch	0.013	4.7	2.5	3.99	110.17	109.56	110.82	110.58	2.7	
P-46	J-20	J-02	10	0.0660	15 inch	0.013	16.6	0.9	6.38	110.21	109.55	110.57	109.76	2.39	
P-02	J-02	J-01	84	0.0001	36 inch	0.013	7.3	37.8	5.55	104.7	104.89	107.74	107.46	6.41	
P-01	J-01	O-1	393	0.0050	33 inch	0.013	37.4	37.7	6.34	104.69	102.2	105.47	105.47	6.33	

Scenario: Existing

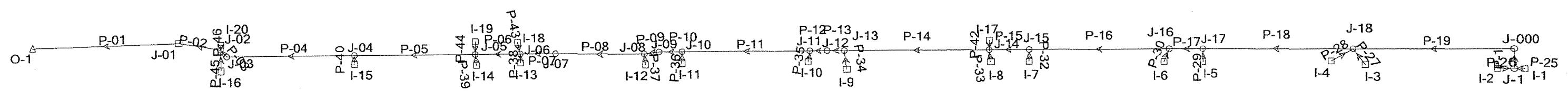


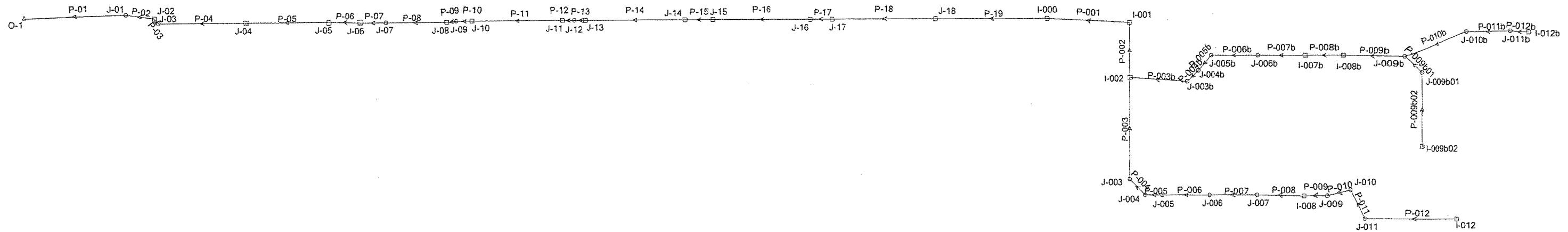
Table 3
BAREC Site
On-site and Forest Avenue Storm Drainage System - Proposed Conditions
10-year Storm Event - Storm CAD results - Nodes with HEC-22 Method Minor Losses

Label	Area (acres)	Inlet CA (acres)	System CA (acres)	Time of Concentration (min)		System Intensity (in/hr)	Total System Flow (cfs)	Rim Hydraulic Grade Line (ft)		Hydraulic Grade Line (ft)		Velocity Out (ft/s)	Standard Loss Method Freeboard
				Flow Time (min)	Intensity (in/hr)			Elevation (ft)	Out (ft)	Freeboard			
I-012	1.92	0.8	0.82	0.8	5.1	2.94	2.4	124.66	119.45	5.21	1.37	5.76	
J-011	0	0	0.8	0.8	8.3	2.2	1.8	123.88	119.31	119.29	4.57	1.02	
J-010	0	0	0	0	9.7	1.99	1.6	123.61	119.26	119.24	4.35	0.93	
J-009	0	0	0	0.8	0	10.9	1.86	123.41	119.22	119.22	4.19	0.87	
J-008	2.8	0.7	1.96	2.8	8.15	12.2	1.74	123.21	119.2	119.17	4.01	2.76	
J-007	0	0	0	2.8	0	13.0	1.67	122.8	118.88	118.85	3.92	2.65	
J-006	0	0	0	2.8	0	13.9	1.61	122.38	118.57	118.54	3.81	2.55	
J-005	0	0	0	2.8	0	14.8	1.56	121.98	118.29	118.26	3.69	2.46	
J-004	0	0	0	2.8	0	15.1	1.53	121.82	118.17	118.06	3.65	2.42	
J-003	0	0	0	2.8	0	15.6	1.5	121.63	117.96	117.85	3.67	2.38	
I-012b	2.1	0.77	1.62	1.6	8.16	8.2	2.21	3.6	119.8	118.34	118.32	2.18	1.09
J-011b	0	0	0	1.6	0	8.9	2.1	3.4	120.5	118.32	118.32	2.18	2.61
J-010b	0	0	0	1.6	0	10.9	1.86	3.0	120.5	118.29	118.28	2.21	0.97
J-009b02	2.39	0.4	0.96	1.0	6.0	6.0	2.66	2.6	122.3	118.45	118.45	3.85	4.31
J-009b01	0	0	0	1.0	0	8.4	2.18	2.1	121.7	118.33	118.3	3.37	1.99
J-009b	0	0	0	2.6	0	14.2	1.59	4.1	121.5	118.24	118.22	3.26	1.31
I-008b	1.01	0.6	0.61	3.2	7.6	16.4	1.46	4.7	122.7	118.17	118.16	4.53	4.96
I-007b	2.91	0.7	2.04	5.2	6.37	17.6	1.4	7.4	122.4	118.12	118.1	4.28	4.71
J-006b	0	0	0.52	0	18.6	1.36	7.1	121.98	117.95	117.94	4.03	2.26	
J-005b	0	0	0.52	0	19.5	1.31	6.9	121.57	117.8	117.72	3.77	2.19	
J-004b	0	0	0.52	0	20.0	1.29	6.8	121.39	117.66	117.64	3.73	2.16	
J-003b	0	0	0.52	0	20.3	1.28	6.7	121.26	117.6	117.52	3.66	2.14	
I-002	1.17	0.7	0.82	8.8	6.77	21.6	1.23	11.0	120.76	117.37	117.23	3.39	3.75
I-001	2.35	0.5	1.17	10.0	8.72	22.4	1.21	12.2	120.29	116.86	116.58	3.43	4.45
I-000	19.37	0.4	7.75	17.7	14.24	24.0	1.16	20.7	119.56	116.37	116.35	3.19	3.42
J-18	9.2	0.4	3.68	21.4	14.4	25.8	1.11	24.0	118.64	116.04	116.02	2.6	2.82
J-17	5.27	0.4	2.11	23.5	14.1	27.3	1.07	26.5	118.22	115.64	115.62	2.58	3.60
J-16	3.36	0.4	1.34	24.9	14.1	27.6	1.07	26.7	118.07	115.52	115.49	2.56	3.78
J-15	3.53	0.4	1.41	26.3	14.1	28.8	1.04	27.5	117.53	115.04	115.02	2.49	3.89
J-14	7.15	0.4	2.86	29.1	14.1	29.2	1.03	30.3	117.47	114.88	114.85	2.59	4.29
J-12	0	0	0	30.4	0	30.4	1.01	30.9	116.73	114.16	114.12	2.57	4.37
J-13	3.22	0.4	1.29	30.4	14.1	30.3	1.01	30.9	116.82	114.26	114.23	2.56	2.82
J-11	3.4	0.4	1.36	31.8	14.1	30.5	1	32.2	116.74	114.04	114	2.7	4.55
J-10	3.49	0.4	1.4	33.2	14.2	31.5	0.99	33.0	116.97	113.4	113.35	2.57	4.67
J-09	0	0	0	33.2	0	31.6	0.98	32.9	116.77	113.24	113.15	2.53	4.65
J-08	10.01	0.4	4	37.2	14.2	31.7	0.98	36.8	115.78	113.07	112.95	2.71	3.20
J-07	0	0	0	37.2	0	32.3	0.97	36.4	115.35	112.42	112.36	2.93	5.15
J-06	6.34	0.4	2.54	39.7	15.8	32.5	0.97	38.7	115.21	112.15	112.09	3.06	5.48
J-05	4.56	0.4	1.82	41.6	15.8	32.8	0.96	40.3	114.87	111.79	111.73	3.08	5.70
J-04	4	0.4	43.2	15.8	33.5	0.95	41.3	114.42	110.86	110.79	3.56	5.84	
J-03	0	0	0	43.2	0	34.2	0.94	40.8	113.61	109.82	109.25	3.79	5.77
J-02	4.99	0.4	2	45.1	15.8	34.3	0.94	42.6	113.15	109.18	108.63	3.97	6.03
J-01	0	0	0	45.1	0	34.5	0.93	42.4	113.79	108.29	108	5.5	5.67
O-1	0	0	0	45.1	0	35.4	0.92	41.8	111	105.47	105.47	5.53	0.00

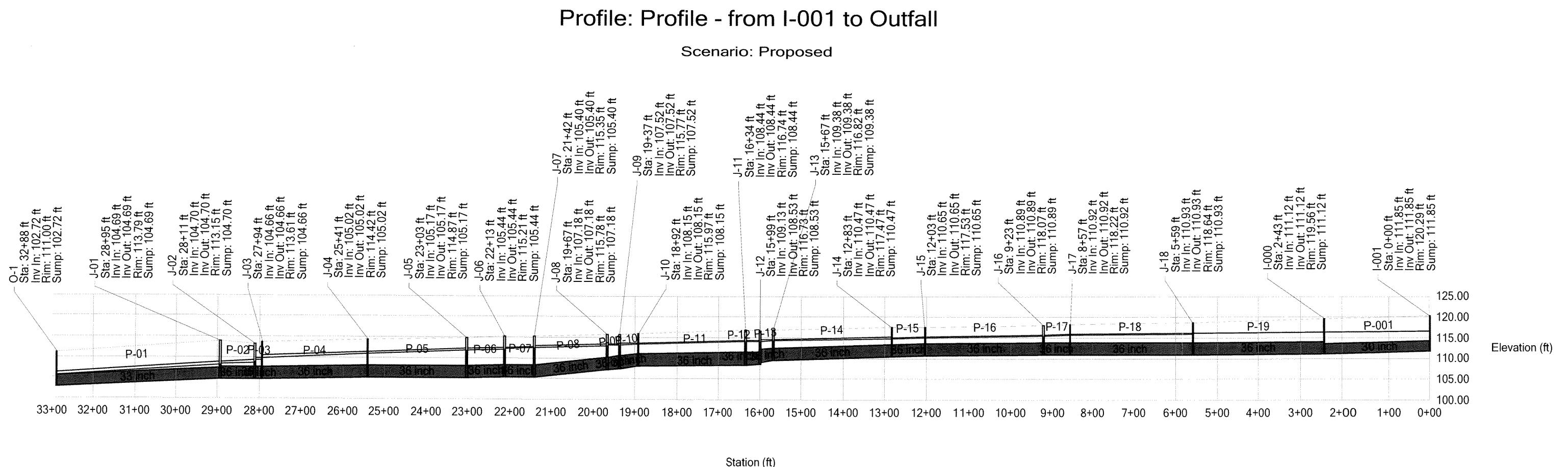
Table 4
BAREC Site
On-site and Forest Avenue Storm Drainage Systems - Proposed Conditions
10-year Storm Event - Storm CAD results - Pipes with HEC-22 Method Minor Losses

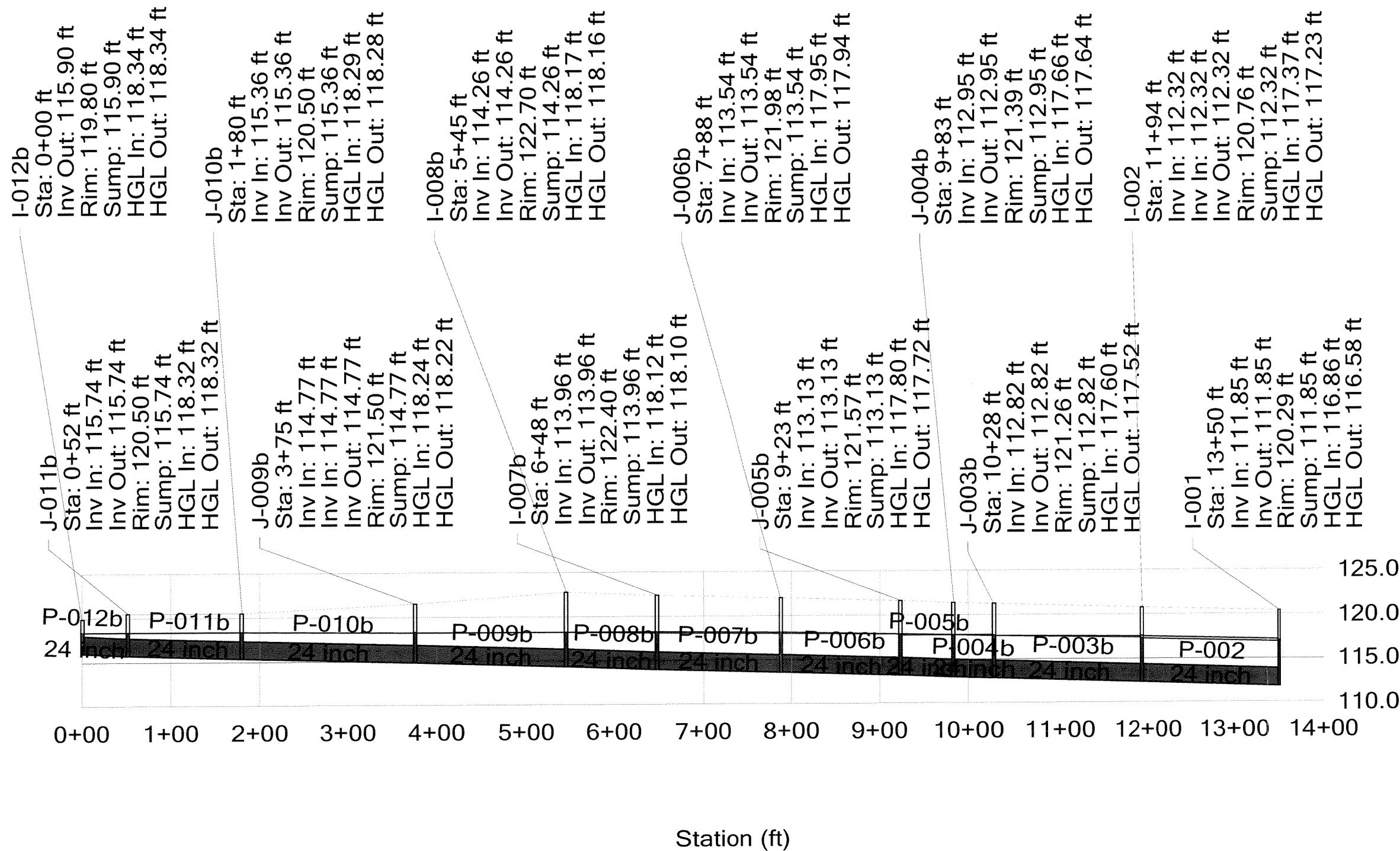
Label	Upstream Node	Downstream Node	Length (ft)	Constructed Slope (ft/ft)	Section Size	Manning's n	Full Capacity (cfs)	System Velocity Out (ft/s)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Upstream Ground Elevation (ft)	Downstream Ground Elevation (ft)	Hydraulic Grade Line In (ft)	Hydraulic Grade Line Out (ft)	Freeboard	Standard Loss Method		Standard Loss Method	
																Hydraulic Grade Line	Hydraulic Grade Line	Hydraulic Grade Line	Hydraulic Grade Line
P-012	J-011	289	0.0030	18 inch	0.013	5.6	2.4	1.37	116.22	115.44	124.66	123.88	119.31	119.45	5.21	4.59	118.80	118.76	5.77
P-011	J-010	91	0.0030	18 inch	0.013	5.7	1.8	1.02	115.44	115.17	123.68	123.61	119.29	119.29	4.37	4.37	118.67	118.69	5.14
P-010	J-010	66	0.0030	18 inch	0.013	5.8	1.6	0.93	115.17	114.97	123.41	123.41	119.24	119.24	4.19	4.19	118.88	118.63	4.91
P-009	J-008	65	0.0031	18 inch	0.013	5.8	1.5	0.87	114.97	114.77	123.41	123.41	119.22	119.22	4.04	4.04	118.86	118.66	4.73
P-008	J-008	137	0.0030	18 inch	0.013	5.8	4.9	2.76	114.77	114.36	123.21	122.8	118.88	118.85	3.95	3.95	118.34	118.06	4.56
P-007	J-006	140	0.0030	18 inch	0.013	5.8	4.7	2.65	114.36	113.94	122.8	122.38	118.85	118.85	3.84	3.84	118.05	117.8	4.33
P-006	J-006	136	0.0029	18 inch	0.013	5.7	4.5	2.56	113.94	113.54	122.38	121.98	118.54	118.29	3.72	3.72	117.78	117.7	4.2
P-005	J-005	62	0.0031	18 inch	0.013	5.8	4.3	2.42	113.54	113.38	121.82	121.63	118.06	117.96	3.76	3.76	117.88	117.75	4.17
P-004	J-004	63	0.0030	18 inch	0.013	5.8	4.3	2.39	113.38	113.19	121.63	120.76	117.86	117.38	3.78	3.78	117.48	117.35	4.15
P-003	J-003	291	0.0030	18 inch	0.013	5.7	4.2	2.39	113.19	112.92	121.63	120.5	118.34	118.32	4.16	4.16	117.91	117.89	4.09
P-012b	J-011b	52	0.0031	24 inch	0.013	3.6	1.5	1.09	115.54	115.36	120.5	120.5	118.32	118.29	2.18	2.18	117.89	117.86	2.61
P-011b	J-011b	128	0.0030	24 inch	0.013	12.3	3.4	1.09	115.74	115.36	120.5	120.5	118.24	118.28	2.22	2.22	117.95	117.92	2.64
P-010b	J-010b	198	0.0030	24 inch	0.013	3.0	0.97	115.36	115.36	120.5	120.5	118.24	118.24	2.22	2.22	117.95	117.92	2.61	
P-009b02	J-009b01	209	0.0030	18 inch	0.013	5.8	1.45	114.97	112.33	122.3	121.7	118.45	118.33	3.85	3.85	117.90	117.86	4.11	
P-008b01	J-008b01	65	0.0031	18 inch	0.013	5.8	2.1	1.19	114.97	114.97	121.7	121.5	118.3	118.27	3.4	3.4	117.85	117.82	3.85
P-008b	J-008b	170	0.0030	24 inch	0.013	12.4	4.1	1.31	114.97	114.86	121.5	121.5	118.22	118.17	3.28	3.28	117.78	117.75	3.7
P-008b	J-008b	103	0.0029	24 inch	0.013	12.2	4.7	1.49	114.26	113.96	122.7	122.1	118.16	119.12	4.54	4.54	117.69	117.66	4.96
P-007b	J-007b	140	0.0030	24 inch	0.013	12.4	1.3	1.09	115.74	115.36	122.4	121.98	118.1	117.95	4.13	4.13	117.58	117.53	4.72
P-006b	J-006b	155	0.0030	24 inch	0.013	12.5	7.1	2.34	113.84	113.13	121.98	121.57	117.94	117.8	4.04	4.04	117.92	117.89	4.16
P-005b	J-005b	60	0.0030	24 inch	0.013	12.4	6.0	2.19	113.13	112.85	121.57	121.39	117.94	117.72	3.85	3.85	117.92	117.89	4.45
P-004b	J-004b	45	0.0029	24 inch	0.013	12.2	6.9	2.16	112.85	112.82	121.39	121.26	117.64	117.58	3.75	3.75	117.86	117.82	4.13
P-003b	J-003b	186	0.0030	24 inch	0.013	12.4	6.7	2.14	112.85	112.82	121.26	121.26	117.52	117.37	3.74	3.74	117.74	117.71	3.7
P-002	J-002	159	0.0030	30 inch	0.013	12.4	11.0	3.49	112.32	111.85	120.76	120.29	118.56	118.37	3.71	3.71	116.92	116.88	3.44
P-001	J-001	243	0.0030	30 inch	0.013	22.5	2.48	1.09	111.85	111.12	120.29	120.29	118.04	118.23	3.21	3.21	116.52	116.52	3.44
P-19	J-19	316	0.0006	36 inch	0.013	16	20.7	2.33	111.12	110.93	119.56	119.56	116.35	116.35	2.62	2.62	116.41	116.38	2.55
P-18	J-18	298	0.0000	36 inch	0.013	3.9	3.39	110.93	110.92	118.64	118.22	116.82	116.82	2.6	2.6	116.26	116.23	2.32	
P-17	J-17	116	0.0005	36 inch	0.013	14.2	25.5	3.6	110.92	110.89	118.22	118.22	116.52	116.52	2.68	2.68	116.25	116.22	2.32
P-16	J-16	280	0.0009	36 inch	0.013	19.5	26.7	3.78	110.89	110.85	118.07	117.93	116.49	116.49	2.62	2.62	116.25	116.22	2.32
P-15	J-15	80	0.0023	36 inch	0.013	31.6	3.66	1.09	110.47	110.53	117.53	117.53	116.88	116.88	2.51	2.51	114.88	114.85	3.34
P-14	J-14	204	0.0038	36 inch	0.013	41.3	30.3	4.29	110.17	109.98	117.47	117.47	114.85	114.85	2.62	2.62	116.85	116.82	3.33
P-13	J-13	32	0.0078	36 inch	0.013	59.0	4.38	109.98	109.13	116.82	116.82	114.23	114.23	2.59	2.59	113.95	113.88	2.87	
P-12	J-12	1	0.0026	36 inch	0.013	33.8	30.9	4.37	108.53	108.44	116.74	116.74	114.04	114.04	3.12	3.12	113.73	113.66	3
P-11	J-11	258	0.0011	36 inch	0.013	22.4	32.2	4.56	108.44	108.15	116.74	115.97	113.54	113.54	2.14	2.14	113.61	113.51	3.13
P-10	J-10	45	0.0140	36 inch	0.013	76.9	33.0	4.67	107.52	107.52	116.97	116.97	113.24	113.24	2.62	2.62	112.98	112.95	3.01
P-09	J-09	30	0.0113	36 inch	0.013	71.0	32.9	4.66	107.52	107.18	116.55	116.55	112.95	112.95	2.62	2.62	112.65	112.62	2.77
P-08	J-08	175	0.0102	36 inch	0.013	67.3	5.2	107.18	105.4	116.25	116.25	112.58	112.58	2.62	2.62	114.58	114.55	2.59	
P-07	J-07	71	-0.0006	36 inch	0.013	11.6	11.6	105.44	105.44	116.35	116.35	114.87	114.87	2.62	2.62	111.92	111.89	3.43	
P-06	J-06	30	0.0030	36 inch	0.013	16.7	5.48	105.44	105.17	116.17	116.17	114.37	114.37	2.62	2.62	111.79	111.76	3.43	
P-05	J-05	238	0.0006	36 inch	0.013	40.3	5.7	105.17	105.02	114.87	114.87	114.32	114.32	2.62	2.62	110.86	110.83	3.43	
P-04	J-04	253	0.0014	36 inch	0.013	25.2	41.3	5.64	105.32	104.66	114.42	114.42	113.81	113.81	2.62	2.62	109.82	109.81	4.36
P-03	J-03	17	-0.0024	36 inch	0.013	32.4	40.8	104.86	104.7	114.69	114.69	113.61	113.61	2.62	2.62	108.47	108.45	4.36	
P-02	J-02	84	0.0001	36 inch	0.013	7.3	42.8	6.03	104.7	104.69	113.16	113.16	108.03	108.03	2.62	2.62	108.12	108.10	5.79
P-01	J-01	393	0.0036	33 inch	0.013	37.4	42.4	7.15	104.69	102.72	113.79	113.79	111	111	2.62	2.62	105.47	105.47	5.79

Scenario: Proposed - alt pipe size



Profile Scenario: Proposed

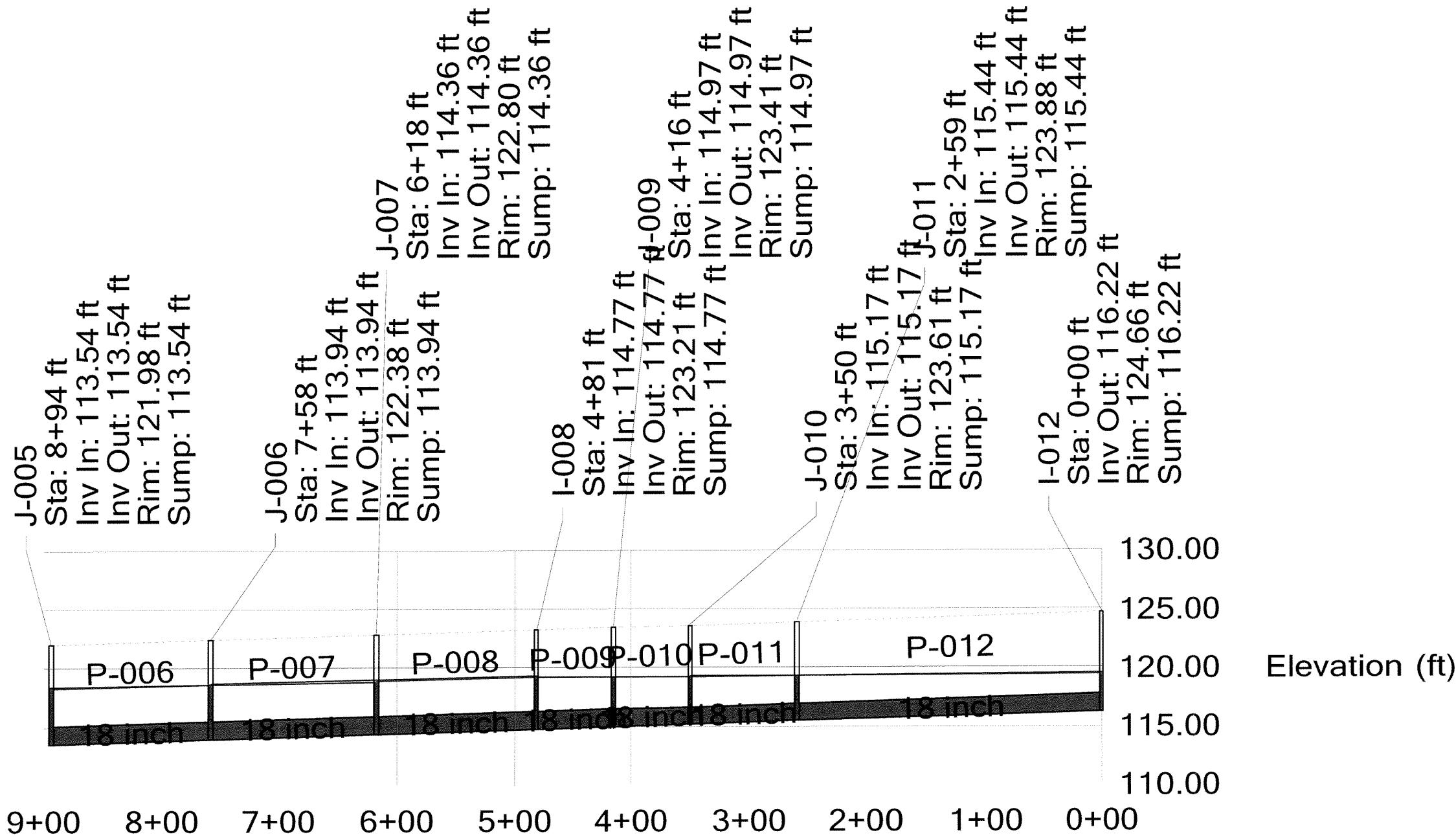




Profile
Scenario: Proposed

Profile: Profile - from I-012 to J-005

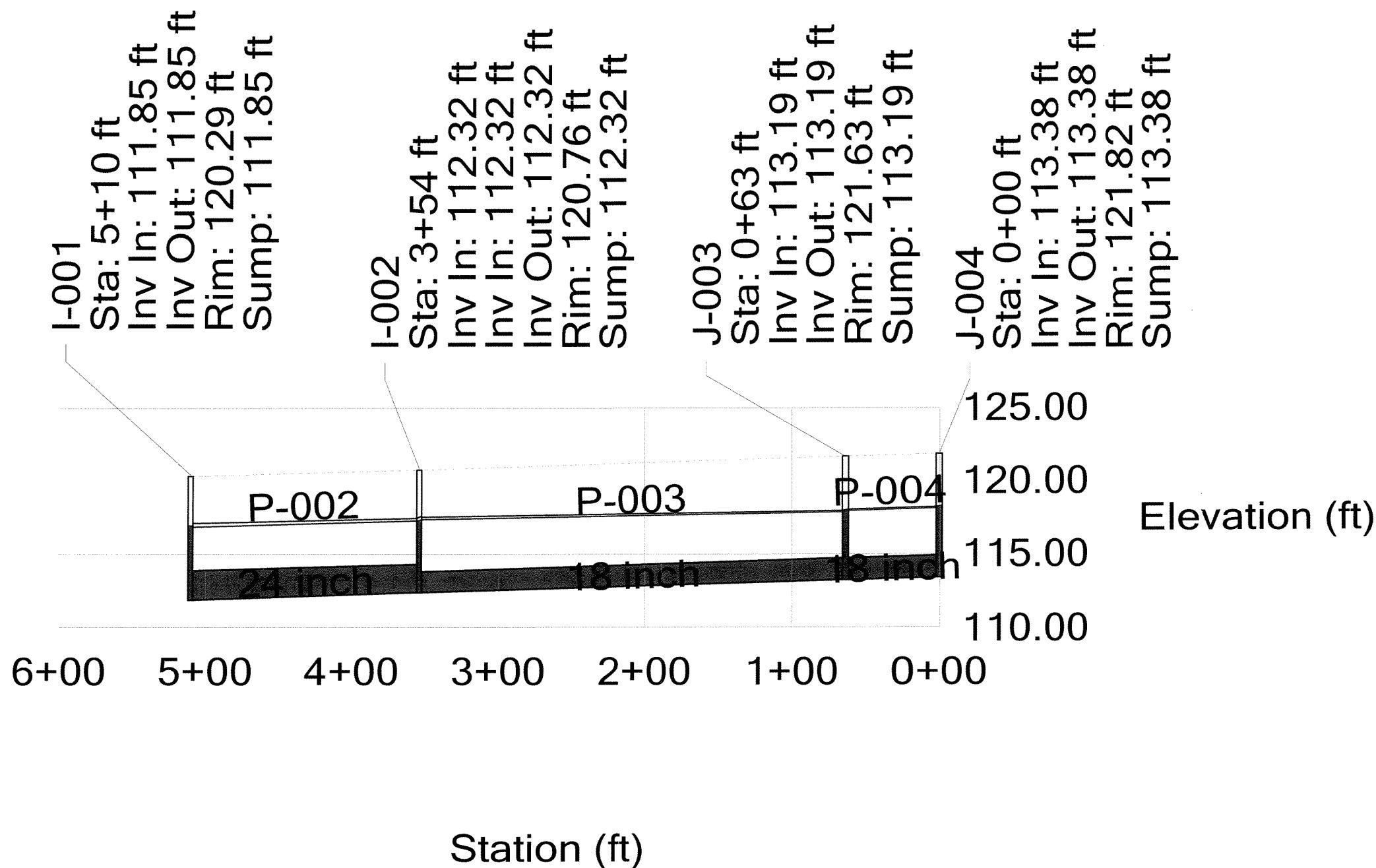
Scenario: Proposed

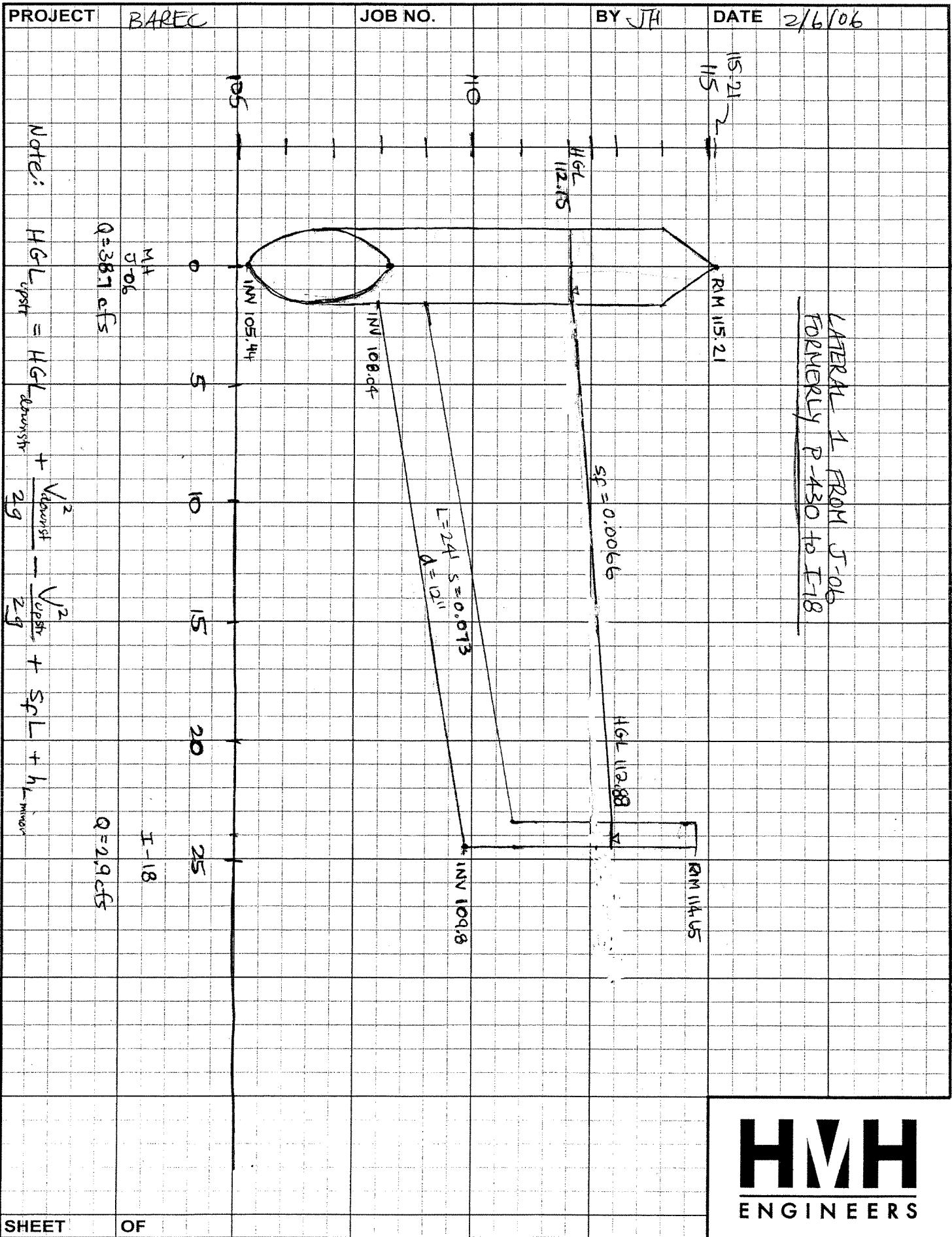


Profile
Scenario: Proposed

Profile: Profile - from J-004 to 001

Scenario: Proposed





PROJECT	BAREC	JOB NO.	BY JH	DATE	2/6/06
				LATERAL 2 FROM J-06 FORMERLY P-380 to I-13	

105

108

110

115

0

5

10

15

17

20

INV 108.36

HGL 112.15

RIM 114.76

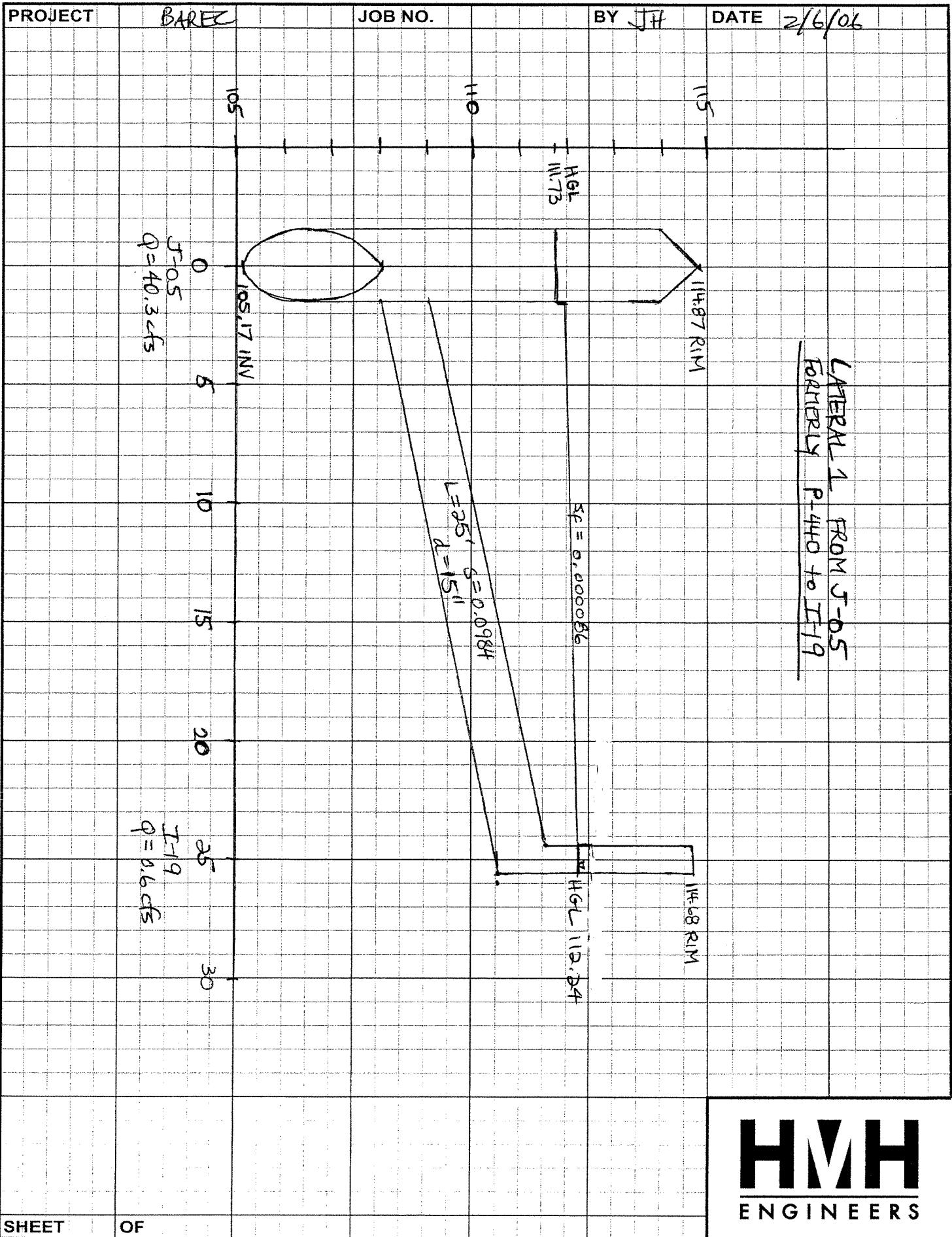
RIM 115.2

HGL 112.76

SC = 0.00ft

L=17' S=0.0853 d=2'

J-06 Q=387



$$J=0.5$$

$$Q=40.3 \text{ cfs}$$

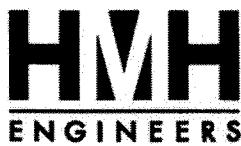
$$I=1.9$$

$$Q=0.6 \text{ cfs}$$

PROJECT	BAREC	JOB NO.		BY	JH	DATE	2/6/06
						LATERAL FROM J-05 FORMERLY P-390 TO I-14	

Diagram showing a trapezoidal channel cross-section with dimensions and flow parameters:

- Top width: 115'
- Bottom width: 105'
- Left side slope: HGL 111.73 - INV 105.42
- Right side slope: INV 107.97 - HGL 112.29
- Length: L = 22'
- Diameter: d = 15"
- Side slope: S = 0.114
- Flow parameters: Q = 40.3 cfs (top) and Q = 2.4 cfs (bottom)



William J. Wagner | Thomas A. Armstrong | Michael L. Morsilli | David M. Wilson | James E. Thompson

Solving for the Energy Equation to Determine the HGL at the Laterals

$$Z_1 + y_1 + \frac{V_1^2}{2g} = Z_2 + y_2 + \frac{V_2^2}{2g} + h_L \quad \text{where 1 is for upstream and 2 is for downstream.}$$

Solving for the upstream node, I-18, the energy equation becomes:

$$HGL_1 = HGL_2 + \frac{V_2^2}{2g} - \frac{V_1^2}{2g} + h_L$$

Minor losses estimated from Urban Drainage Design Manual, HEC-22, November 1996, p. 7-14:

$$h_L = K_{ah} \frac{V_o^2}{2g} \quad K_{ah} = \text{Loss coefficient for an access hole}$$

V_o = Outlet pipe velocity

Lateral 1 from J-06, formerly Pipe P-430 to I-18

$$HGL_{I-18} = HGL_{J-06} + \frac{V_{J-06}^2}{2g} - \frac{V_{I-18}^2}{2g} + h_L$$

from Manning's we find the friction slope for $Q_{I-18} = 2.9$ cfs

$$Q = \frac{1.486}{0.013} \pi \left[\frac{12/12}{2} \right]^2 \left[\frac{12/12}{4} \right]^{2/3} S_f^{0.5} \quad \rightarrow \quad S_f = 0.0066$$

Then,

$$HGL_{I-18} = 112.15 + \frac{5.48_{J-06}^2}{2g} - \frac{3.69_{I-18}^2}{2g} + 0.0066 * 24' + 0.318 = 112.88'$$

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Lateral 2 from J-06, formerly Pipe P-380 to I-13

$$HGL_{I-13} = HGL_{J-06} + \frac{V_{J-06}^2}{2g} - \frac{V_{I-13}^2}{2g} + h_L$$

from Manning's we find the friction slope for $Q_{I-13} = 2.3$ cfs

$$Q = \frac{1.486}{0.013} \pi \left[\frac{12/12}{2} \right]^2 \left[\frac{12/12}{4} \right]^{2/3} S_f^{0.5} \quad \Rightarrow \quad S_f = 0.00416$$

Then,

$$HGL_{I-18} = 112.15 + \frac{5.48_{J-06}^2}{2g} - \frac{2.96_{I-18}^2}{2g} + 0.00416 * 17' + 0.204 = 112.76$$

Lateral 1 from J-05, formerly Pipe P-440

$$HGL_{I-19} = HGL_{J-05} + \frac{V_{J-05}^2}{2g} - \frac{V_{I-19}^2}{2g} + h_L$$

from Manning's we find the friction slope for $Q_{I-19} = 0.6$ cfs

$$Q = \frac{1.486}{0.013} \pi \left[\frac{15/12}{2} \right]^2 \left[\frac{15/12}{4} \right]^{2/3} S_f^{0.5} \quad \Rightarrow \quad S_f = 0.0000863$$

Then,

$$HGL_{I-19} = 111.73 + \frac{5.7_{J-05}^2}{2g} - \frac{0.51_{I-19}^2}{2g} + 0.0000863 * 25' + 0.006 = 112.24$$

Lateral 2 from J-05, formerly Pipe P-390

$$HGL_{I-14} = HGL_{J-05} + \frac{V_{J-05}^2}{2g} - \frac{V_{I-14}^2}{2g} + h_L$$

from Manning's we find the friction slope for $Q_{I-14} = 2.4$ cfs

$$Q = \frac{1.486}{0.013} \pi \left[\frac{15/12}{2} \right]^2 \left[\frac{15/12}{4} \right]^{2/3} S_f^{0.5} \quad \Rightarrow \quad S_f = 0.00138$$

Then,

$$HGL_{I-14} = 111.73 + \frac{5.7_{J-06}^2}{2g} - \frac{1.96_{I-14}^2}{2g} + 0.00138 * 22' + 0.089 = 112.29$$

Date: 2/7/2006
 Job Number: 3081
 Designed: JAH
 Checked:
 Manning's n 0.013
 $I = 0.669/Tc^{0.6}$ K 0.669
 n 0.6
 MAP 14.7
 equivalent diameter of structure 4 ft
 10 year storm

TABLE 5
BAREC Homes Development Project Storm Sewer Design Sheet
Showing Minor Losses for the Laterals to I-13, I-18, I-14, and I-19

POC	A	C	C'A	$\Sigma C'A$	Tc	STCAD	I	design Q	S	Id - 14.7	V	L	Tf	H _i	Main <	Side <	Area1	g(a+a)/2	Jct Loss	Kah	Hah	Invert	HGL	water depth	EGL	TC Elev	Cover	Freeboard		
I-012	1.02	0.80	0.82	0.82	5.1	2.94	2.94	2.40							0.13			1.8					116.22	119.87	3.65	119.87	124.66	6.94	4.79	
J-011		0.00	0.82	8.28	2.20	2.19	1.79		0.003	18	2.4	259	3.18		0.026	0.0		1.8	57	0.000			115.44	119.71	4.27	119.73	123.88	6.94	4.17	
J-010		0.00	0.82	9.8	1.99	1.99	1.62		0.003	18	1.0	91	1.50		0.016	0.0		1.8	57	0.000			115.17	119.69	4.52	119.71	123.61	6.94	3.92	
J-009		0.00	0.82	11.0	1.86	1.85	1.51		0.003	18	0.9	66	1.20		0.013	0.0		1.8	57	0.000			114.97	119.68	4.71	119.69	123.41	6.94	3.73	
I-008	2.80	0.70	1.96	2.78	12.2	1.75	1.74	4.82							0.29	0.0		1.8	57	0.208			114.77	119.67	4.90	119.68	123.21	6.94	3.54	
J-007		0.00	2.78	13.1	1.68	1.67	1.63		0.003	18	2.7	137	0.84		0.27	0.0		1.8	57	0.000			114.36	119.07	4.71	119.18	122.80	6.94	3.73	
J-006		0.00	2.78	14.0	1.62	1.60	1.45		0.003	18	2.6	140	0.89		0.24	0.0		1.8	57	0.000			113.94	118.81	4.87	118.91	122.38	6.94	3.57	
J-005		0.00	2.78	14.9	1.57	1.54	1.29		0.003	18	2.5	136	0.90		0.086	0.0		1.8	57	0.000			113.54	118.57	5.03	118.67	121.98	6.94	3.41	
J-004		0.00	2.78	15.2	1.55	1.52	1.23		0.003	18	2.4	52	0.36		0.10	0.0		1.8	57	0.000			113.38	118.49	5.11	118.58	121.82	6.94	3.33	
J-003		0.00	2.78	15.7	1.52	1.50	1.16		0.003	18	2.4	63	0.44		0.45	0.0		1.8	57	0.000			113.19	118.39	5.20	118.48	121.63	6.94	3.24	
I-012b	2.10	0.77	1.62	1.62	8.16	2.21	2.21	3.58							0.06	0.0		1.8	57				115.90	118.94	3.04	118.94	119.80	2.40	0.86	
J-011b		0.00	1.62	8.6	2.15	2.15	3.47		0.003	18	2.0	52	0.43		0.03	0.0		3.1	79	0.000			115.74	118.82	3.08	118.88	120.50	2.76	1.68	
J-010b		0.00	1.62	10.5	1.99	1.90	3.08		0.003	24	1.1	128	1.93		0.04	60.0		3.1	79	0.014			115.36	118.83	3.47	118.85	120.50	3.14	1.67	
J-009b	2.39	0.40	0.96	2.57	13.8	1.80	1.61	4.15		0.003	24	1.0	195	3.32		0.06	0.0		3.1	101	0.024			114.77	118.79	4.02	118.80	121.50	4.73	2.71
I-008b	1.01	0.60	0.61	3.18	16.0	1.64	1.48	4.70		0.003	24	1.3	170	2.14		0.044	0.0		3.1	101	0.015			114.26	118.69	4.43	118.72	122.70	6.44	4.01
I-007b	2.91	0.70	2.04	5.22	17.1	1.57	1.42	7.40		0.003	24	1.5	103	1.15		0.149	0.0		3.1	101	0.103			113.96	118.63	4.67	118.66	122.40	6.44	3.77
J-006b		0.00	5.22	18.1	1.51	1.37	7.16		0.003	24	2.3	135	0.99		0.134	0.0		3.1	101	0.000			113.54	118.32	4.78	118.41	121.98	6.44	3.66	
J-005b		0.00	5.22	19.1	1.46	1.33	6.93		0.003	24	2.2	60	0.45		0.056	0.0		3.1	101	0.000			113.13	118.19	5.06	118.27	121.57	6.44	3.38	
J-004b		0.00	5.22	19.6	1.44	1.31	6.84		0.003	24	2.2	45	0.34		0.041	0.0		3.1	101	0.000			112.95	118.14	5.19	118.22	121.39	6.44	3.25	
J-003b		0.00	5.22	19.9	1.43	1.30	6.77		0.003	24	2.2	166	1.28		0.15	0.0		3.1	101	0.000			112.82	118.10	5.28	118.18	121.26	6.44	3.16	
I-002	1.17	0.70	0.82	8.81	21.2	1.37	1.25	11.01	0.003	24	3.5	156	0.74		0.37	90.0	0.0	3.1	101	0.285			112.32	117.96	5.64	118.03	120.76	6.44	2.80	
I-001	2.35	0.50	1.18	9.99	21.9	1.35	1.22	12.22	0.003	30	2.5	243	1.63		0.21	90.0		4.9	130	0.235			111.85	117.19	5.34	117.38	120.29	5.94	3.10	

POC	A	C	C'A	$\Sigma C'A$	Tc	STCAD	I	design Q	S	d - 14.7	V	L	Tf	H _r	Main <	Side <	Area1	$g(a+a)/2$	Jct Loss	Kah	Hah	Invert	HGL	water dept	EGL	TC Elev	Cover	Freeboard		
															Inlet Losses															
J-000	19.37	0.40	7.75	17.73	23.6	1.31	1.17	20.79							0.31	0.0		7.1	193	0.159			111.12	116.83	5.71	116.93	119.56	5.44	2.73	
									0.003	36	2.9	316	1.79																	
J-18	9.20	0.40	3.68	21.41	25.3	1.25	1.12	24.02		0.00	36	3.4	298	1.46		0.38	0.0		7.1	228	0.090			110.93	116.33	5.40	116.46	118.64	4.71	2.31
J-17	5.27	0.40	2.11	23.52	26.8	1.21	1.08	25.52		0.0005	36	3.61	66	0.30		0.10	0.0		7.1	228	0.046			110.92	115.81	4.89	115.99	118.22	4.30	2.41
J-16	3.36	0.40	1.34	24.87	27.1	1.20	1.08	26.79		0.0009	36	3.79	280	1.23		0.45	0.0		7.1	228	0.041			110.89	115.64	4.75	115.85	118.07	4.18	2.43
J-15	3.53	0.40	1.41	26.28	28.3	1.17	1.05	27.57		0.0023	36	3.90	80	0.34		0.14	0.0		7.1	228	0.026			110.65	115.13	4.48	115.36	117.53	3.88	2.40
J-14	7.15	0.40	2.86	29.14	28.7	1.16	1.04	30.35		0.0038	36	4.29	284	1.10		0.58	0.0		7.1	228	0.100			110.47	114.96	4.49	115.19	117.47	4.00	2.51
J-13	3.22	0.40	1.29	30.43	29.8	1.14	1.02	30.98		0.0078	36	4.38	32	0.12		0.07	0.0		7.1	228	0.024			109.38	114.22	4.84	114.51	116.82	4.44	2.60
J-12			0.00	30.43	29.9	1.14	1.02	30.91		0.0026	36	4.37	35	0.13		0.07	0.0		7.1	228	0.000			108.53	114.12	5.59	114.42	116.73	5.20	2.61
J-11	3.40	0.40	1.36	31.79	30.0	1.13	1.01	32.20		0.0011	36	4.56	258	0.94		0.60	0.0		7.1	228	0.051			108.44	114.04	5.60	114.34	116.74	5.30	2.70
J-10	3.49	0.40	1.40	33.18	31.0	1.11	0.99	33.00		0.014	36	4.67	45	0.16		0.11	0.0		7.1	228	0.032			108.15	113.37	5.22	113.69	115.97	4.82	2.60
J-09			0.00	33.18	31.1	1.11	0.99	32.90		0.0113	36	4.65	30	0.11		0.07	0.0		7.1	228	0.000			107.52	113.21	5.69	113.55	115.77	5.25	2.56
J-08	10.04	0.40	4.02	37.20	31.3	1.11	0.99	36.80		0.0102	36	5.21	175	0.56		0.53	0.0		7.1	228	0.169			107.18	113.14	5.96	113.48	115.78	5.60	2.64
J-07			0.00	37.20	31.8	1.10	0.98	36.41		-0.0006	36	5.15	71	0.23		0.21	0.0		7.1	228	0.000			105.40	112.36	6.96	112.78	115.35	6.95	2.99
I-13	3.90	0.40	1.56	1.56	15.8		1.49	2.32		0.085	12	2.96	17	0.10		0.07	90.0			1.5	20.20	109.80	112.64	2.84	112.64	114.65	3.85	2.01		
I-18	2.44	0.40	0.98	0.98	5.0		2.97	2.90		0.072	12	3.69	24	0.11		0.16	90.0			1.5	20.20	109.80	112.73	2.93	112.73	114.65	3.85	1.92		
J-06		0.40	0.00	39.73	32.0	1.09	0.97	38.73		0.003	36	5.48	90	0.27		0.30	0.0		7.1	228	0.108			105.44	112.16	6.72	112.57	115.21	6.77	3.05
I-14	4.03	0.40	1.61	1.61	15.8		1.49	2.40		0.111	15	1.96	22	0.19		0.03	90.0			1.5	20.00	109.80	111.54	1.74	111.54	114.65	3.60	3.11		
I-19	0.53	0.40	0.21	0.21	5.0		2.97	0.63		0.098	15	0.51	25	0.81		0.002	90.0			1.5	20.00	109.80	111.52	1.72	111.52	114.65	3.60	3.13		
J-05		0.40	0.00	41.56	32.3	1.09	0.97	40.30		0.0006	36	5.70	238	0.70		0.86	0.0		7.1	228	0.077			105.17	111.05	5.88	111.51	114.87	6.70	3.82
J-04	4.00	0.4	1.60	43.16	33.0	1.07	0.96	41.32		0.0014	36	5.8	253	0.72		0.97	0.0		7.1	228	0.052			105.02	110.02	5.00	110.52	114.42	6.40	4.40
J-03			0.00	43.16	33.7	1.06	0.95	40.79		-0.0024	36	5.8	17	0.05		0.06	0.0		7.1	228	0.000			104.66	108.97	4.31	109.50	113.61	5.95	4.64
J-02	4.99	0.40	2.00	45.15	33.8	1.06	0.94	42.63		0.0001	36	6.03	84	0.23		0.34	0.0		7.1	228	0.096			104.70	108.92	4.22	109.44	113.15	5.45	4.23
J-01			0.00	45.15	34.0	1.05	0.94	42.46		0.005	33	7.15	393	0.92		2.52	0.0		5.9	209	0.221			104.69	108.44	3.75	109.00	113.79	6.35	5.35
Outfall			0.00	45.15	34.9	1.04	0.93	41.79															102.72	105.47	2.75	106.26	111.00	8.28	5.53	

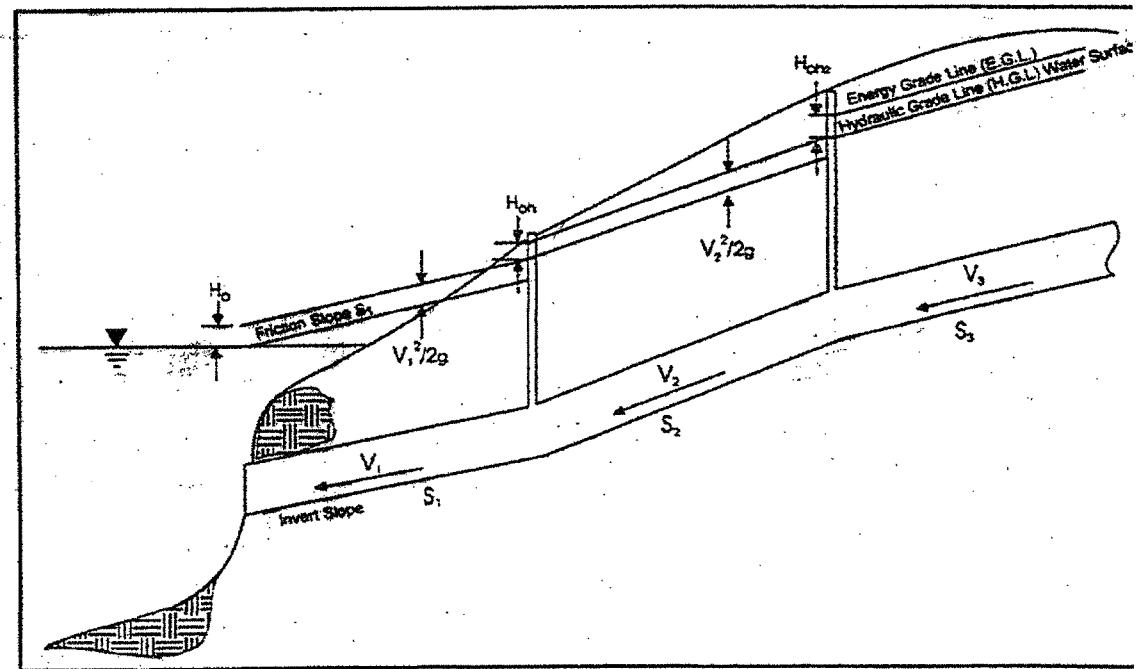


U.S. Department
of Transportation
Federal Highway
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Office of Engineering
Office of Technology Applications
400 7th Street, N.W.
Washington, D.C. 20590

URBAN DRAINAGE DESIGN MANUAL

Hydraulic Engineering Circular No. 22



November 1996



Chapter 7. Storm Drains

7.1.6.5 Junction Losses

A pipe junction is the connection of a lateral pipe to a larger trunk pipe without the use of an access hole structure. The minor loss equation for a pipe junction is a form of the momentum equation as follows:

$$H_j = \frac{(Q_o V_o) - (Q_i V_i) - (Q_l V_l \cos \theta)}{0.5 g (A_o + A_i)} + h_i - h_o \quad (7-8)$$

where: H_j = junction loss, m (ft)
 Q_o, Q_i, Q_l = outlet, inlet, and lateral flows respectively, m^3/s (ft^3/s)
 V_o, V_i, V_l = outlet, inlet, and lateral velocities, respectively, m/s (ft/s)
 h_o, h_i = outlet and inlet velocity heads, m (ft)
 A_o, A_i = outlet and inlet cross-sectional areas, m^2 , (ft^2)
 θ = the angle between the inflow and outflow pipes (see figure 7-4).

7.1.6.6 Inlet and Access Hole Losses - Preliminary Estimate

An approximate method for computing losses at access holes or inlet structures involves multiplying the velocity head of the outflow pipe by a coefficient as represented in equation 7-9. Applicable crown coefficients (K) are tabulated in table 7-5a. This method can be used to estimate the initial pipe crown drop across an access hole or inlet structure to offset energy losses at the structure. The crown drop is then used to establish the appropriate pipe invert elevations, as demonstrated in example 7-3. However, this method is only for preliminary estimation and should not be used for the actual design process.

$$H_{ah} = K_{ah} \left(\frac{V_o^2}{2g} \right) \quad (7-9)$$

7.1.6.7 Inlet and Access Hole Losses - Energy-Loss Methodology

Two (2) methodologies have been advanced for evaluating losses at access holes and other flow junctions, the energy loss and power loss methods. Both methods are based on laboratory research and do not apply when the inflow pipe invert is above the water level in the access hole. This section presents the energy loss methodology.

The energy loss encountered going from one pipe to another through an access hole is commonly represented as being proportional to the velocity head of the outlet pipe. Using K to represent the constant of proportionality, the energy loss, H_{ah} , is approximated by equation 7-10. Experimental studies have determined that the K value can be approximated by the relationship in equation 7-11 when the inflow pipe invert is below the water level in the access hole.

$$H_{ah} = K \left(\frac{V_o^2}{2g} \right) \quad (7-10)$$

$$K = K_o C_D C_d C_Q C_p C_B \quad (7-11)$$

where:

K	= adjusted loss coefficient
K_o	= initial head loss coefficient based on relative access hole size
C_D	= correction factor for pipe diameter (pressure flow only)
C_d	= correction factor for flow depth
C_Q	= correction factor for relative flow
C_p	= correction factor for plunging flow
C_B	= correction factor for benching
V_o	= velocity of outlet pipe

 Table 7-5a. Head loss coefficients ⁽⁴⁰⁾

STRUCTURE CONFIGURATION	K_{ah}
Inlet - straight run	0.50
Inlet - angled through	
90°	1.50
60°	1.25
45°	1.10
22.5°	0.70
Manhole - straight run	0.15
Manhole - angled through	
90°	1.00
60°	0.85
45°	0.75
22.5°	0.45

For cases where the inflow pipe invert is above the access hole water level, the outflow pipe will function as a culvert, and the access hole loss and the access hole HGL can be computed using procedures found in *Hydraulic Design of Highway Culverts* (HDS-5)⁽²⁾. If the outflow pipe is flowing full or partially full under outlet control, the access hole loss (due to flow contraction into the outflow pipe) can be computed by setting K in equation 7-10 to K_e as reported in Table 7-5b. If the outflow pipe is flowing under inlet control, the water depth in the access hole should be computed using the inlet control nomographs in HDS- 5 (for example see charts 28 and 29).

The initial head loss coefficient, K_o in equation 7-11, is estimated as a function of the relative access hole size and the angle of deflection between the inflow and outflow pipes as represented in equation 7-12. This deflection angle is represented in figure 7-4.

$$K_o = 0.1 \left(\frac{b}{D_o} \right) (1 - \sin\theta) + 1.4 \left(\frac{b}{D_o} \right)^{0.15} \sin\theta \quad (7-12)$$

where: θ = the angle between the inflow and outflow pipes (see figure 7-4)
 b = access hole or junction diameter
 D_o = outlet pipe diameter

A change in head loss due to differences in pipe diameter is only significant in pressure flow situations when the depth in the access hole to outlet pipe diameter ratio, d_{ah}/D_o , is greater than 3.2. In these cases a correction factor for pipe diameter, C_D , is computed using equation 7-13. Otherwise C_D is set equal to 1.

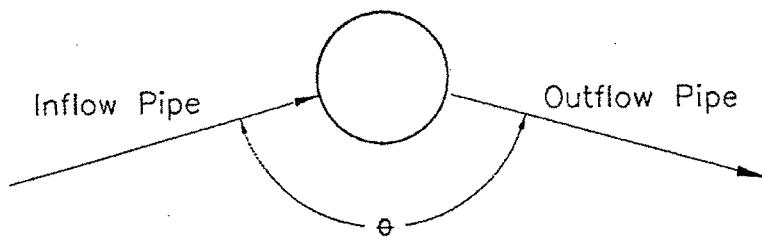


Figure 7-4. Deflection angle.

$$C_D = \left(\frac{D_o}{D_i} \right)^3 \quad (7-13)$$

where: D_o = outgoing pipe diameter
 D_i = inflowing pipe diameter

The correction factor for flow depth, C_d , is significant only in cases of free surface flow or low pressures, when the d_{sho}/D_o ratio is less than 3.2. In cases where this ratio is greater than 3.2, C_d is set equal to 1. To determine the applicability of this factor, the water depth in the access hole is approximated as the level of the hydraulic grade line at the upstream end of the outlet pipe. The correction factor is calculated using equation 7-14.

$$C_d = 0.5 \left(\frac{d_{sho}}{D_o} \right)^{0.6} \quad (7-14)$$

where: d_{sho} = water depth in access hole above the outlet pipe invert
 D_o = outlet pipe diameter

The correction factor for relative flow, C_Q , is a function of the angle of the incoming flow as well as the percentage of flow coming in through the pipe of interest versus other incoming pipes. It is computed using equation 7-15. The correction factor is only applied to situations where there are 3 or more pipes entering the structure at approximately the same elevation. Otherwise, the value of C_Q is equal to 1.0.

$$C_Q = (1 - 2 \sin \theta) \left(1 - \frac{Q_i}{Q_o} \right)^{0.75} + 1 \quad (7-15)$$

where: C_Q = correction factor for relative flow
 θ = the angle between the inflow and outflow pipes (see figure 7-4)
 Q_i = flow in the inflow pipe
 Q_o = flow in the outflow pipe

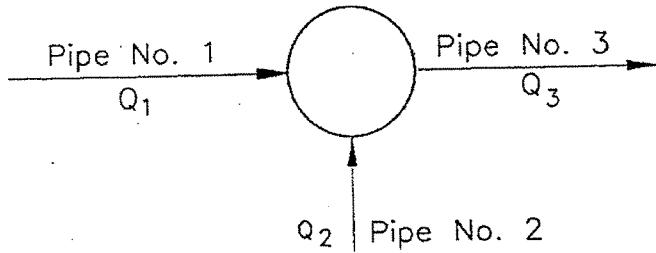


Figure 7-5. Relative flow effect.

As can be seen from equation 7-15, C_Q is a function of the angle of the incoming flow as well as the percentage of inflow coming through the pipe of interest versus other incoming pipes. To illustrate this effect, consider the access hole shown in figure 7-5 and assume the following two cases to determine the correction factor of pipe number 2 entering the access hole. For each of the two cases, the angle between the inflow pipe number 1 and the outflow pipe, θ , is 180° .

$$\text{Case 1: } Q_1 = 0.9 \text{ m}^3/\text{s} (3 \text{ ft}^3/\text{s})$$

$$Q_2 = 0.3 \text{ m}^3/\text{s} (1 \text{ ft}^3/\text{s})$$

$$Q_3 = 1.2 \text{ m}^3/\text{s} (4 \text{ ft}^3/\text{s})$$

Using equation 7-15,

$$C_Q = (1 - 2 \sin \theta)(1 - Q_1/Q_3)^{0.75} + 1$$

$$C_Q = (1 - 2 \sin 180^\circ)(1 - 0.9/1.2)^{0.75} + 1$$

$$C_Q = 1.35$$

$$\text{Case 2: } Q_1 = 0.3 \text{ m}^3/\text{s} (1 \text{ ft}^3/\text{s})$$

$$Q_2 = 0.9 \text{ m}^3/\text{s} (3 \text{ ft}^3/\text{s})$$

$$Q_3 = 1.2 \text{ m}^3/\text{s} (4 \text{ ft}^3/\text{s})$$

$$\text{Using equation 7-15, } C_Q = (1 - 2 \sin \theta)(1 - Q_1/Q_3)^{0.75} + 1$$

$$C_Q = (1 - 2 \sin 180^\circ)(1 - 0.3/1.2)^{0.75} + 1$$

$$C_Q = 1.81$$

The correction factor for plunging flow, C_p , is calculated using equation 7-16. This correction factor corresponds to the effect another inflow pipe, plunging into the access hole, has on the inflow pipe for which the head loss is being calculated. Using the notations in figure 7-5, C_p is calculated for pipe #1 when pipe #2 discharges plunging flow. The correction factor is only applied when $h > d_{\text{thr}}$. Additionally, the correction factor is only applied when a higher elevation flow plunges into an access hole that has both an inflow line and an outflow in the bottom of the access hole. Otherwise, the value of C_p is equal to 1.0.

Table 7-6. Correction for benching.

Bench Type	Correction Factors, C_B	
	Submerged *	Unsubmerged **
Flat or Depressed Floor	1.00	1.00
Half Bench	0.95	0.15
Full Bench	0.75	0.07

* pressure flow, $d_{sho}/D_o > 3.2$
** free surface flow, $d_{sho}/D_o < 1.0$

$$C_p = 1 + 0.2 \left(\frac{h}{D_o} \right) \left(\frac{h - d_{sho}}{D_o} \right) \quad (7-16)$$

where: C_p = correction for plunging flow
 h = vertical distance of plunging flow from the flow line of the higher elevation inlet pipe to the center of the outflow pipe.
 D_o = outlet pipe diameter
 d_{sho} = water depth in access hole relative to the outlet pipe invert

The correction for benching in the access hole, C_B , is obtained from table 7-6. Figure 7-6 illustrates benching methods listed in table 7-6. Benching tends to direct flow through the access hole, resulting in a reduction in head loss. For flow depths between the submerged and unsubmerged conditions, a linear interpolation is performed.

In summary, to estimate the head loss through an access hole from the outflow pipe to a particular inflow pipe using the energy-loss method, multiply the above correction factors together to get the head loss coefficient, K . This coefficient is then multiplied by the velocity head in the outflow pipe to estimate the minor loss for the connection.

7.1.6.8 Inlet and Access Hole Losses - Power-Loss Methodology

The power-loss methodology was developed in response to the need for an energy loss relationship which would cover the wide range of flow conditions which occur in access holes⁽⁴²⁾. This procedure estimates energy losses at access holes for free-surface, transitional, and pressure flows. Two-pipe, three-pipe, and four-pipe configurations were evaluated during development of the methodology.

The power-loss methodology is based on the premise that minor energy losses through an access hole can be determined using a conservation of power concept. The power entering the access hole can be equated to the sum of the outflow power and the power lost. The solution of the equation involves selection of an initial value of the depth of flow in the access hole, d_{sho} , and computation of the inflow power, outflow power, and the power loss in the access hole until the equality is achieved. Computation of losses are dependent on the initial value of d_{sho} selected and the adjusted d_{sho} values determined during the iterative processes.